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This week's issue

On the cover

32 Does the universe have a memory?
The imprints of the past left in space-time, and what they could reveal

New Scientist
DOES THE UNIVERSE HAVE A MEMORY?

Vol 259 No 3450
Cover image: sleeplesseyes

10 Assessing claims of a room-temperature superconductor

15 First evidence for the life-extending power of young blood

36 The cooling Pacific: The biggest mystery in climate science

11 The origin of Indo-European languages
14 Cracks that break the laws of physics
30 Season two of Asimov's *Foundation*

32 Features

> **"It would be evidence of a hidden form of symmetry thought to saturate the whole universe"**

News

8 Ancient arson
Charred remains in Jerusalem reveal Babylonian burning

13 Immune therapy
How cancer-fighting immune cells could be made better

18 Wood not so good
Building with wood may not be as climate-friendly as thought

Views

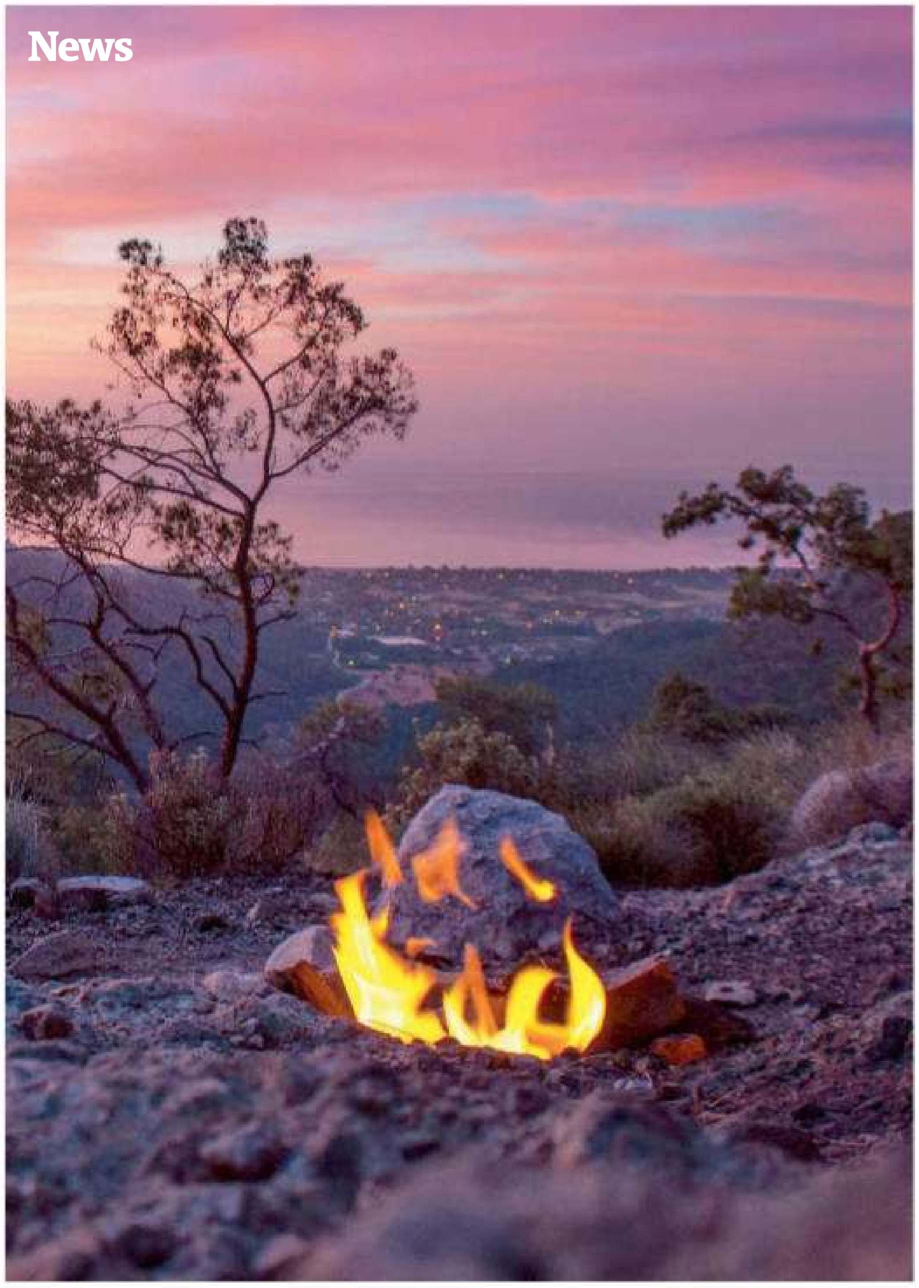
21 Comment
Dan Levitt on the cognitive biases scientists face

22 The columnist
Annalee Newitz on the rise of automated AI content

24 Aperture
The Endeavour space shuttle is prepped for display

26 Letters
There is no easy way to tackle the obesity epidemic

28 Culture
A book spurs a conversation about conversation



SVITLANA BELINSKA/ALAMY

12 Burning issue Is underground hydrogen a green energy solution?

Features

32 Space-time never forgets
The search for "gravitational memory" and what it would reveal about the universe

36 A mystery in the Pacific
Why is a vast part of the ocean off Ecuador cooling instead of warming, as we would expect?

40 Dietary supplements
Examining the evidence behind the claimed benefits

The back pages

44 60-second psychology
How to turn down commitments

45 Puzzles
Try our crossword, quick quiz and logic puzzle

46 *Almost* the last word
Why do almost all vertebrates have tails?

48 Feedback
Woolly science and going creak at the knees

48 Twisteddoodles for *New Scientist*
Picturing the lighter side of life

Elsewhere on New Scientist

NS Live

Are psychedelics the future of mental health?

Jonathan Iliff, a doctor working in the NHS in London, will explore the use of psychedelic drugs to treat mental health conditions at New Scientist Live on 7 October. Join him to discover how psychedelics produce their effects in the brain, whether people might benefit from compounds such as psilocybin and LSD, and if they will ever be prescribed in the UK.

newscientist.com/nslmag

Tour

Total Solar Eclipse 2024: Houston to San Antonio, US

One of nature's most magnificent events – a total solar eclipse – will be seen in North and Central America on 8 April 2024 and Texas is the perfect spot to witness it. This eight-day tour, visiting astronomical and geological sites, begins on 3 April 2024 and costs £4399.

newscientist.com/tours

Podcasts

Weekly

On this week's podcast, the team discuss whether scientists really made a room-temperature superconductor or not. We hear how mRNA nanoparticles can be used to reprogram mice bone marrow, about innovative methods for rescuing coral in hot oceans and why your hands are heavier than you think. Plus, the sounds of a star's internal twinkle.

newscientist.com/nspod

STEFAN ROTTER/SHUTTERSTOCK

Choughed to hear it Charismatic corvids reintroduced in Kent, UK

NIKOLAY PANDEV/GETTY IMAGES

Twinkle twinkle Listen to the sounds of stars

Video

Return of the choughs

Red-billed choughs are charismatic corvids related to crows and jackdaws, with a bright red bill, red legs and a distinctive call. Now, these once-persecuted birds, which have been in decline for many years, have been reintroduced near the iconic white cliffs of Dover in south-east England after a 200-year absence.

youtube.com/newscientist

Newsletter

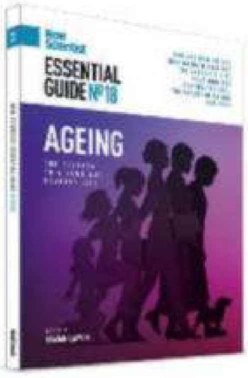
Fix the planet

It might surprise you to hear that many medicines, including painkillers, are made from petrochemicals. Madeleine Cuff talks to researchers who are trying to develop a plant-based method for manufacturing painkillers that could pave the way to decarbonising medicine.

newscientist.com/fix-the-planet

Newsletter

> **"Consumers might pay more if they were aware painkillers are contributing to climate change"**



Essential guide

What drives the ageing process? What can science tell us about the stages of life? And how can we use the latest research to live healthily into old age? This *New Scientist Essential Guide* offers some fresh insight. Available to download in the *New Scientist* app or to purchase in print from our shop.

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A promising puck

Claims of a superconductor breakthrough could lead to progress, even if they are wrong

IN A video seen by millions on social media, a thin, grey puck floats on one edge atop a magnet. It never fully levitates and so isn't quite the smoking gun it should be. Its creators say the puck is a revolutionary new material, one that could transform science and technology. Others are sceptical that it really is what they say it is. Either way, the puck has generated an intense wave of interest and that, in of itself, could be valuable.

Superconductors, materials that perfectly conduct electricity without losing any energy to resistance, were first discovered more than a century ago. Yet our understanding of how they work and our ability to make them are both limited.

The best description of what causes superconductivity comes from a framework developed in the 1950s called BCS theory. This says superconductivity is the result of electrons pairing up in such a way that they avoid generating electrical resistance when they move, but it tells us little of use about how to make such a material.

> "This flurry of research activity could be just what the search for new superconductors needs"

That hasn't stopped the search. However, every superconductor found and confirmed so far only works under the extreme conditions of ultra-low temperatures and ultra-high pressures. This makes them impractical for most applications.

If one were found that worked in a more comfortable environment, it could transform technologies that use electricity and enable everything from making the power grid more environmentally friendly to bringing nuclear fusion closer to viability.

So it is no wonder a little puck that might just be a room-temperature, ambient-pressure superconductor has grabbed a lot of attention (see page 10).

The history of superconductors is littered with claims that haven't stood up to further scrutiny, so scepticism is, of course, the right approach. But with research groups already racing to try to replicate the experiments, this flurry of activity could be just what the search for new superconductors needs to make progress. ■

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© 2023 New Scientist Ltd, England.
New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd

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News

Accelerated ageing
Women seem to age fastest in their 30s and 50s p9

Plasma patterns
How the magnetic fields around galaxies could arise p11

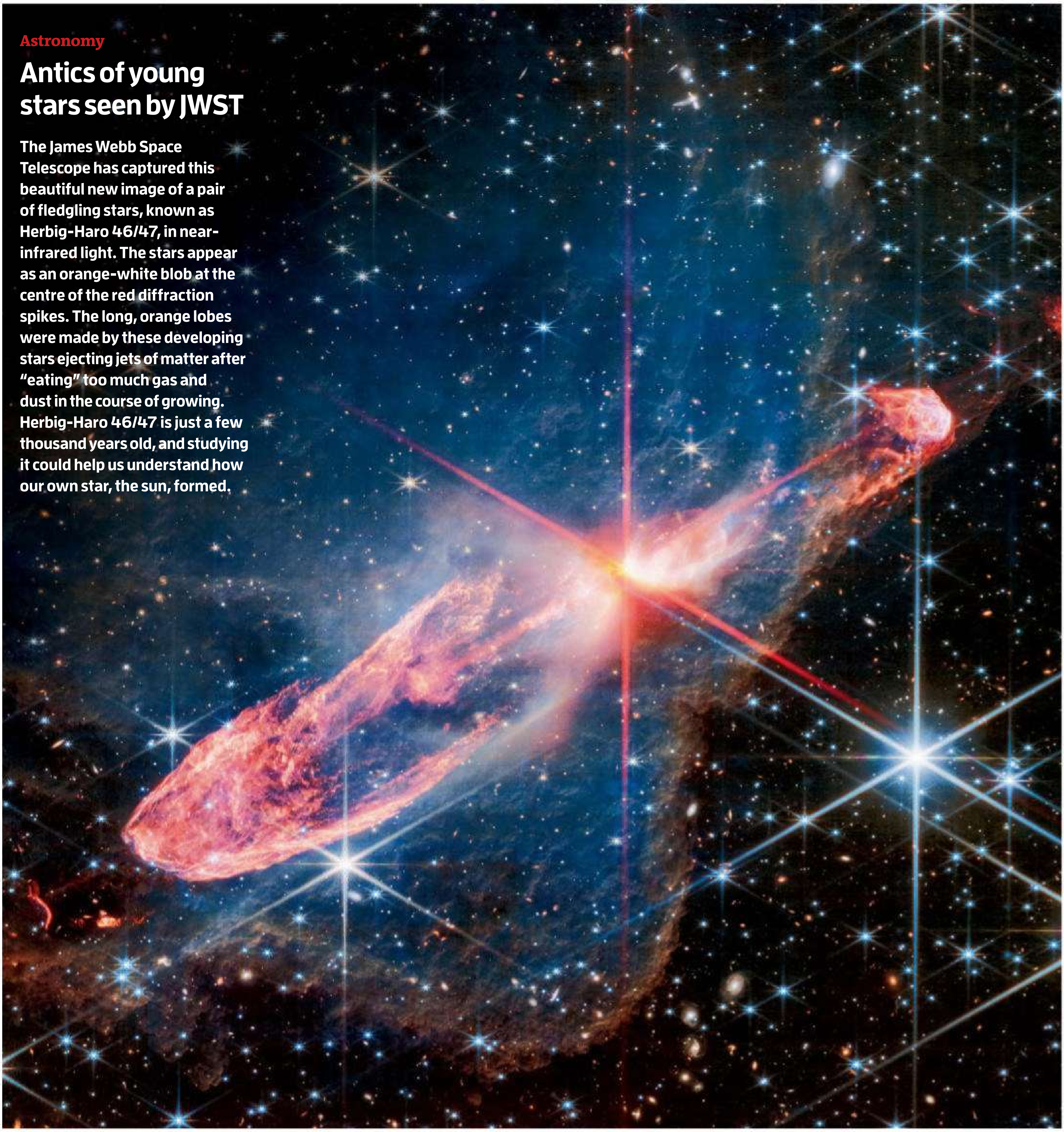
Erratic timing
Start of spring in the Arctic is increasingly unpredictable p16

Ancient cover-up
Hints that cosmetic use was widespread in ancient China p17

Lazy lovers
Lizards put less effort into courting when it gets hot p19

Astronomy

Antics of young stars seen by JWST



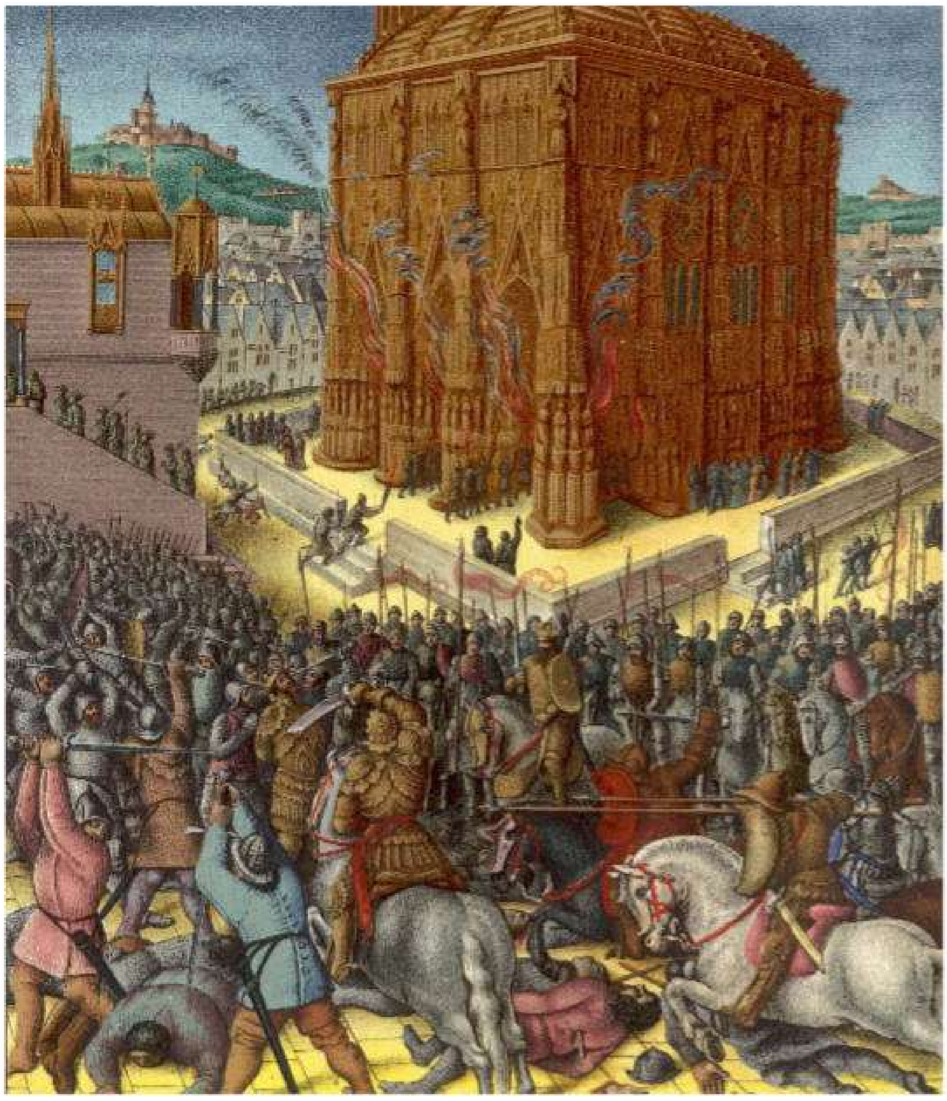
The James Webb Space Telescope has captured this beautiful new image of a pair of fledgling stars, known as Herbig-Haro 46/47, in near-infrared light. The stars appear as an orange-white blob at the centre of the red diffraction spikes. The long, orange lobes were made by these developing stars ejecting jets of matter after "eating" too much gas and dust in the course of growing. Herbig-Haro 46/47 is just a few thousand years old, and studying it could help us understand how our own star, the sun, formed.

NASA, ESA, CSA, J. DEPASQUALE (STSCI)

Archaeology

Babylonian arson uncovered

By analysing the charred remains of a building in Jerusalem, archaeologists have revealed details of how it was burned by Babylonian invaders in 586 BC, finds **Michael Marshall**



CHRONICLE/ALAMY

The Babylonian siege of Jerusalem, as illustrated by Jean Fouquet in the 15th century

ARCHAEOLOGISTS have reconstructed how Babylonian invaders burned down a building in Jerusalem more than 2500 years ago, by analysing chemical clues in the debris. The building was destroyed as part of the Babylonian conquest of the Kingdom of Judah, which is presented as a turning point in the story of Judaism in the Hebrew Bible.

Beginning in 601 BC, Judean kings launched a series of unsuccessful rebellions against the Babylonians, who had taken control of the region under King Nebuchadnezzar II. This culminated in 587 BC, when the Babylonians besieged the Judean capital of Jerusalem for about a year and a half.

When Jerusalem finally surrendered in 586 BC, the Babylonians destroyed much of the city. But the historical record of this is poor. "The Babylonian chronicles from these years were not preserved," says Nitsan Shalom at Tel Aviv University in Israel.

As a result, the biblical version of events is the only account. It claims comprehensive devastation, says Shalom. "There was a violent and complete destruction, the whole city was burned and it stayed completely empty, like the descriptions you see in Lamentations about the city deserted and in complete misery," she says. Famously, Solomon's Temple was destroyed.

Shalom and her colleagues are excavating a site called Building 100 on the south-eastern hill of ancient Jerusalem. "We don't have the whole site, but just the part we do have is already one of the largest buildings in the city at the time," says Shalom. It is at least 10 metres by 17 metres, with three rooms arranged in a row. There may be more of the building to the north of the known rooms.

The building was constructed from finely hewn stones called ashlars. It had two storeys and the upper level had an unusual plaster floor. The team has also found imported ivory and the remains of jars that held spiced wine. "The people here were rich and could get their hands on very unique commodities," says Shalom.

"They targeted the more important buildings in the city, as a way of sending a political message"

It was obvious from the debris and charred remains that the building had caught fire and the upper floor had collapsed. To reconstruct what happened, Shalom and her colleagues used two techniques. One, based on the absorption of infrared light, enabled them to estimate to what degree a piece of debris or sediment had been heated.

Similarly, archaeomagnetism revealed whether items that contained magnetic minerals had become hot enough to reorient the magnetic compounds to a new magnetic north (*Journal of Archaeological Science*, doi.org/kms5).

The analyses show that several fires were lit in the building. The team didn't find any evidence for extra fuel, says Shalom, probably because the building already contained a lot of wooden furniture and other flammable material. In addition, the arsonists probably ignited the beams that held the second storey, she says.

Burning the beams meant the upper storey collapsed – probably all at once, according to previous archaeomagnetic studies of the floor fragments by some members of the team.

"Many of them recorded the same magnetic north in the location where they were found," says Shalom. This implies they were still joined to each other when they fell.

The collapse of the upper floor would have quenched the fires, which weren't particularly hot, staying below 400°C (750°F). However, the extent of the debris suggests people went back in and knocked down any remaining walls. "I'm not sure it would collapse so completely as we found it without help," says Shalom.

While Building 100 was thoroughly destroyed, many other preserved buildings in Jerusalem show little or no sign of damage. In a study published in March, Shalom reviewed previous archaeological digs focused on the Babylonian destruction. "The picture is not actually that uniform," she says. "You're not really finding this picture of complete devastation everywhere that you're digging."

Shalom suggests that the Babylonians didn't destroy indiscriminately. Instead, "they targeted the more important, the more famous buildings in the city", as a way of sending a political message that the Judean elite had failed and resistance to the Babylonian Empire was futile.

In this view, it was a symbolic act designed to break morale – and it hit home. "2600 years later, we're still mourning the temple," says Shalom. ■

Ageing

Women may age fastest when they are in their 30s and 50s

Alice Klein

WOMEN tend to experience accelerated ageing around the ages of 30 and 50, according to a study that analysed a wide range of molecular and physical markers. This may be due to hormonal changes that occur when some women give birth or go through the menopause.

There is growing recognition that ageing doesn't always progress at the same pace and factors such as stress and smoking can speed it up.

Scientists have developed several ways to gauge the rate of ageing, including measuring the length of cells' telomeres (pieces of DNA that protect the ends of chromosomes), analysing facial dimensions and looking at epigenetic markers (signs of genes being influenced by the environment) on DNA. However, the accuracy of these measures may be limited if they are used on their own, says Weiqi Zhang at the Beijing Institute of Genomics in China.

Now, Zhang and her colleagues have conducted the most comprehensive study yet of ageing in women by combining multiple different measures.

> "Hormone replacement therapy can alleviate the decline in hormones, potentially slowing ageing"

The researchers recruited 113 women aged 20 to 66 who had no known medical conditions and were from Quzhou, a city in south-east China. No transgender people were included in the study.

The researchers collected samples of the volunteers' blood, urine and faeces. They also photographed their faces, asked them about their diet and other lifestyle factors and took more than 100 clinical measurements, including their height and weight, blood pressure, lung capacity, grip strength and ability to stand on one leg.

Next, they analysed the expression of the participants' genes and proteins, as well as their telomere lengths, facial dimensions, gut microbiomes, hormones, lipids, immune markers and a range of other measures, to establish a composite ageing clock.

Their analysis revealed that the women tended to be biologically "younger" than their chronological age if they had healthy diets that included eating plenty of fruits and grains.

It also found that the participants around the ages of 30 and 50 typically displayed the fastest rate of ageing. These are often the ages that some women give birth or experience the menopause, both of which are associated with hormonal changes, says Zhang. "These results indicate that the pace of female ageing might be, at least partially, regulated by the hormone regulation system."

Intriguingly, the participants aged 45 and older who were on hormone replacement therapy to treat menopause symptoms seemed to display slower ageing than those who weren't (*Med*, doi.org/kmp9). "Hormone replacement therapy can alleviate the decline in circulating hormones, potentially slowing the rate of [ageing]," says Zhang.

However, because the study included a relatively small number of participants, further research is needed to confirm its findings, she says. The team is now planning to conduct a similar study in men to find out if they display different patterns of ageing. ▮

Zoology

Nightingales match their rivals' pitch during singing duels

MALE nightingales can adjust the pitch of their songs to precisely match the songs of other males, just as we modulate our tone of voice during a conversation.

Male common nightingales (*Luscinia megarhynchos*), a migratory bird found in Europe, Asia and Africa, can have repertoires of some 150 to 200 song types, one of which is known as a whistle song. During the mating season, males perform these songs in nighttime musical duels to defend territory and attract mates.

Giacomo Costalunga at the Max Planck Institute for Biological Intelligence in Germany and his colleagues recorded whistle songs from pairs of male nightingales during their mating season in Brandenburg, Germany. They also conducted playback experiments during the mating season and at the birds' wintering grounds in The Gambia in West Africa.

They found that nightingales adjusted the pitch of their whistle songs to match that of their opponent. When the researchers played pitch-controlled artificial whistle sounds, the nightingales also matched their pitch across a wide range of frequencies.

"These findings show how flexible the singing behaviour of these birds is," says Costalunga.

When they responded within 2 seconds, the birds' pitch matching was more precise than if they tried after 6 to 8 seconds, suggesting they have only a brief memory of the sound they are imitating (*Current Biology*, doi.org/kmqk).

DAVID TIPLING PHOTO LIBRARY/ALAMY

Nightingales sing to defend territory and attract mates

It is unclear why the nightingales replicate the pitch of other males' whistles, or how a duel's winner is decided. It might be that females choose mates based on their pitch-matching, says Costalunga.

The researchers found that the birds could still match pitch in the winter, when they rarely sing and don't mate.

"From a behavioural point of view, it suggests that there's some kind of information that is being conveyed in these non-breeding interactions," says Stephen Nowicki at Duke University, North Carolina.

Costalunga and his colleagues hope to unravel the neural underpinnings of pitch matching in nightingales by recording the birds' brain activity as they reproduce the pitch of whistles. ▮

Alakananda Dasgupta

Technology

Scepticism over superconductor

Claims of a breakthrough in creating a material that perfectly conducts electricity at room temperature and pressure are attracting scrutiny, finds **Karmela Padavic-Callaghan**

A TEAM of researchers claims to have created the first materials that conduct electricity perfectly at room temperature and pressure, but many physicists are sceptical. Speaking to *New Scientist*, Hyun-Tak Kim at the College of William & Mary in Virginia says he will support anyone trying to replicate his team's work.

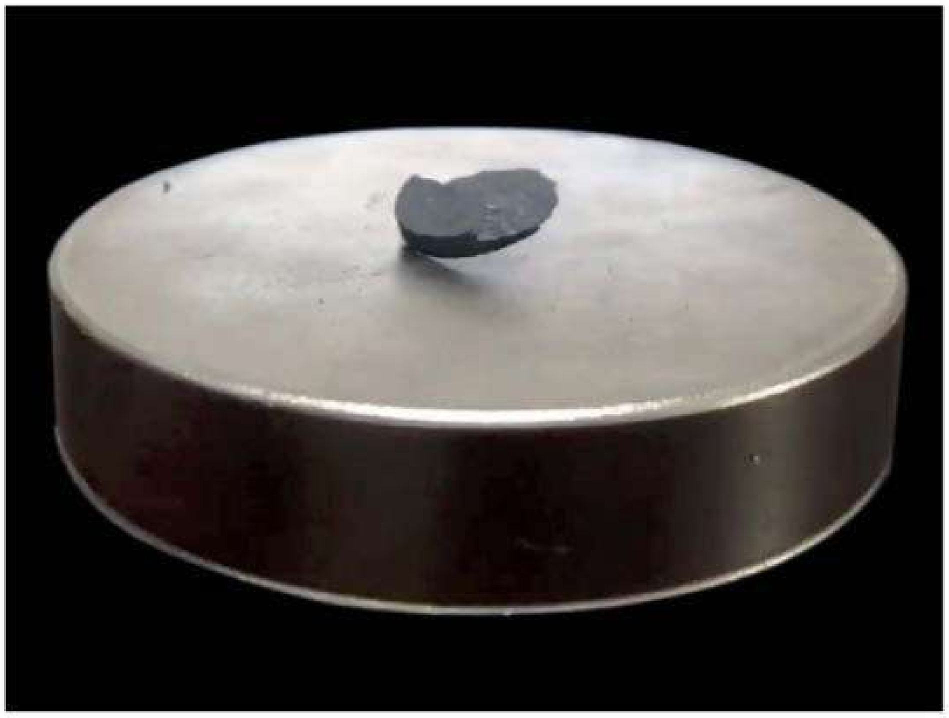
Superconductors are materials through which electricity can move without encountering any resistance, and so would cut down the energy costs of electronics. But for over a century, researchers have been unable to make them work except under extreme conditions like very low temperatures and high pressures.

Now, Kim and his colleagues claim to have made a material that is superconductive at room temperature and pressure.

If their claims hold up to scientific scrutiny, this new work would be truly extraordinary, so the burden of proof is equally exceptional. The fact that some previous reports of breakthroughs in superconductivity were later retracted and that other teams failed to replicate those results also raises the stakes.

To make the new material, called LK-99, Kim and his colleagues mixed several powdered compounds containing lead, oxygen, sulphur and phosphorus, then heated them at a high temperature for several hours. This made the powders chemically react and transform into a dark grey solid.

They then measured how much a millimetre-sized sample of LK-99 resisted electricity passing through it at different temperatures in ambient air pressure and found that its resistivity fell from a sizeable positive value at 105°C (221°F) down to nearly zero at 30°C (86°F).


HYUN-TAK KIM ET AL. (2023)

A piece of the material known as LK-99 partially levitating above a magnet

Kim and his team also tested the material's response to a magnetic field at a range of temperatures because superconductors are known to expel them as part of a phenomenon called the Meissner effect. They concluded that it did exhibit this effect in the temperature range where it also had near zero resistance.

Because of the Meissner effect, a superconductor floats when placed on a conventional magnet, and the researchers filmed a test of this levitation as well. In their video, they place a piece of LK-99 above a magnet and it clearly rises above the magnet's surface.

However, only one edge of the piece levitates, while the other seems to stay in contact with the magnet (pictured). Kim says this is due to the sample being imperfect, which means only part of it becomes superconductive.

Currently, two papers concerning LK-99 are available on the preprint service arXiv, which doesn't conduct peer review, and a related past study was published in the *Journal of the Korean Crystal Growth and Crystal Technology* in April. Kim has only co-authored one of the arXiv papers (doi.org/kk42), while the other is written by his colleagues at the Quantum Energy Research Centre and Korea University in South Korea (doi.org/kk43), some of whom also applied for a patent on LK-99 in August 2022.

Both papers present similar measurements, but Kim says he takes issue with parts of the second paper and it was uploaded to arXiv without his permission. In that paper, the work is described as opening a "new era for humankind".

> **"In one arXiv paper, the superconductor work is described as opening a 'new era for humankind'"**

Some commentators on social media heralded the findings as a generational breakthrough, but the overwhelming response from superconductivity researchers has been largely sceptical.

Susannah Speller and Chris Grovenor at the University of Oxford say that when a material becomes superconductive, there should be clear signatures of that in a number of measurements.

Experimental errors?

For two of those signatures – the response to a magnetic field and a quantity called heat capacity – Speller says neither is demonstrated in the data. "So it is too early to say that we have been presented with compelling evidence for superconductivity in these samples," she says.

Other experts, who declined to speak on the record, told *New Scientist* they are similarly sceptical about the results and the data produced. Some raised concern that some results could be explained by errors in experimental procedure combined with imperfections in the LK-99 sample.

The theoretical models that Kim and his colleagues cite as explaining why the new material can superconduct at such different conditions than all previous ones have also been called into question by one of the researchers that *New Scientist* spoke to. However, computer simulations of how electrons move in materials of the same type as LK-99 carried out at Lawrence Berkeley National Laboratory in California indicate that some arrangements of its main elements may lead to unusual properties, including superconductivity.

Kim says he is aware of the scepticism, but believes that other researchers should try to replicate his team's work to settle the issue. Once the findings are published in a peer-reviewed journal, which Kim says is in the works, he will support anyone who wants to create and test LK-99 for themselves. ▮

Space

We may finally know how galaxy-scale magnetic fields arise

Leah Crane

SIMULATIONS are revealing how the churning plasma that once filled the universe could have created powerful magnetic fields.

Lorenzo Sironi at Columbia University in New York and his colleagues simulated turbulence in plasma to study a phenomenon called the Weibel instability. In turbulent fluids, asymmetries can develop when more particles happen to be moving in one direction than the others. These asymmetries in charged particles cause tiny magnetic fields to arise.

The Cigar Galaxy (also called M82), has its own strong magnetic field

JPL; NASA/SOFIA/E. LOPEZ-RODRIGUEZ

The researchers found that the Weibel instability creates a small "seed" magnetic field, which forces charged particles to bunch together. That clumping, along with the swirling plasma, drives an increase in magnetism. "The turbulence takes these magnetic field lines and twists them, stretches them, folds them and that effectively makes them stronger," says Sironi. This could grow a tiny magnetic field to the galactic and even intergalactic scales we see now, they found. The work will be published in *Physical Review Letters*.

Stars and planets can generate magnetic fields via internal processes, but it has been tougher to work out the origins of magnetic fields in galaxies, galaxy clusters and the spaces between them.

"This is a mechanism for magnetising the universe," says Sironi. Understanding the magnetic fields could also help us figure out the properties of turbulent plasmas across the universe. ▮

Cultural evolution

Indo-European languages traced back 8000 years

Jason Arunn Murugesu

THE common ancestor of Indo-European languages, which are spoken by nearly half the world's population, was spoken in the eastern Mediterranean around 8000 years ago, according to an analysis of related words.

Indo-European languages, spanning from English to Sanskrit, have long been thought to share a common ancestor. The first linguist to make this link, William Jones, said in 1786 that no linguist could examine Greek, Latin and Sanskrit together "without believing them to have sprung" from some common ancestor.

But researchers have struggled to agree on the origin story of this proto-Indo-European language, says Paul Heggarty, who is now at the Pontifical Catholic University of Peru. There are two main hypotheses, he says. The first suggests that the language originated in the steppe region, north of the Black Sea, no earlier than 6500 years ago and then spread across Europe and parts of Asia with the domestication of horses.

The second, known as the farming theory, argues that the language originated in the north of the Fertile Crescent, in what is now south-east Turkey and north-west Iran, as early as 9500 years ago and spread to other regions with farming.

To test these ideas, Heggarty and his colleagues created a database of 170 words, such as "night" and "fire", and their translations in 161 Indo-European languages, including 52 non-modern languages, such as ancient Greek.

By analysing shared patterns between words, the researchers could estimate how related the languages were to each other and try to piece together when one language split into two new ones. "Languages don't really have a date of birth, but you can see where there's a split," says Heggarty. "English is related to German, but these lineages separated from each other around 2000 years ago."

Using this analysis, the team estimates that the root of all Indo-European languages dates back to about 8100 years ago. There is a good chance it originated in the Fertile Crescent as hypothesised by the farming theory, the researchers report. But while the farming theory suggests a close link between Indo-Iranic languages, such as Hindi, and Balto-Slavic languages, such as Latvian, the study found no clear evidence for this (*Science*, doi.org/gsjc8f).

Instead, the researchers theorise that Indo-European languages spread in multiple directions from the Fertile Crescent. "One of those directions took it to the steppe, and from there, there was a secondary expansion to Europe," says Heggarty.

"Languages don't really have a date of birth, but you can see where there's a split"

They think this European expansion would have happened about 5000 years ago, as proposed by the steppe hypothesis. It is backed by DNA data that suggests there was a massive migration into Europe from the steppe region around that time. The team suggests that the Indo-Iranic branch of the language broke off earlier, around 7000 years ago.

This "hybrid" idea takes aspects of both the steppe and farming hypotheses. "This is the best framework to be working with now, as more research is coming in, especially from ancient DNA," says Heggarty.

This is unlikely to be the final word on the origin of Indo-European languages, but it is a step in the right direction, says James Clackson at the University of Cambridge. "The open access database [of word meanings] is particularly welcome," he says. ▮

Farmers 8000 years ago may have spread an early Indo-European language

DAVID KILPATRICK/ALAMY

Analysis Hydrogen fuel

Is geologic hydrogen a green energy solution?

Plans to extract hydrogen from underground reservoirs have been presented as climate-friendly, but it is unclear how much they could increase global warming, says **Michael Le Page**

A GROWING number of companies are interested in extracting hydrogen gas from under the ground, with at least one claiming it is "zero carbon". Now, the first assessment of this kind of geologic hydrogen production has found that while it would still lead to increased global warming, this would be comparable to or lower than hydrogen production from renewable sources. However, at least one expert thinks the study underestimates the warming effect.

Burning hydrogen produces only water, so it is widely seen as a green alternative to natural gas, which releases emissions including carbon dioxide and methane when burned. However, at present, most hydrogen is produced from natural gas, which means the greenhouse gas emissions relating to using hydrogen are still high.

A few companies are producing so-called blue hydrogen, which involves capturing some of these emissions. Then there is green hydrogen, made by splitting water using power from wind or solar, thus keeping emissions down.

Huge uncertainties

Now, there is a new contender, known as geologic hydrogen, which is produced deep underground by processes such as rocks reacting with water. Largely ignored until recently, it is now attracting a lot of commercial interest. Last month, for instance, a start-up called Koloma revealed that it has raised $90 million to explore geologic hydrogen production.

But huge uncertainties remain about how much hydrogen could be extracted. "As it is so early in development, we don't have much information about how abundant and cheap it will be to produce geologic hydrogen, so it remains to be seen whether or not it can be a major energy source," says Adam Brandt at Stanford University in California.

WESTEND61 GMBH/ALAMY

Flames burning at Mount Chimaera in Turkey, fuelled by underground gas

It is also unclear what geologic hydrogen's environmental impact would be, so Brandt has made the first estimate of its likely greenhouse emissions in a study funded by Smart Gas Sciences, a company interested in geologic hydrogen.

One issue is that while hydrogen isn't a greenhouse gas, it alters atmospheric chemistry in a way that increases the lifespan of greenhouse gases, such as methane. This means any hydrogen leakage causes global warming.

Geological hydrogen also contains varying amounts of methane and nitrogen, so the gas must be purified and compressed before transport and use, which requires energy and so can lead to further emissions.

> "It remains to be seen whether or not geologic hydrogen can be a major energy source"

As a base case, Brandt assumed a source that is 85 per cent hydrogen, 12 per cent nitrogen and 1.5 per cent methane, where waste gas is re-injected underground and the process is powered using some of the hydrogen. In this case, he estimates that the production of 1 kilogram of pressured hydrogen would result in the emission of the equivalent of 0.4 kilograms of carbon dioxide.

However, emissions would be several times higher in various scenarios. If the waste gas were burned off, the carbon intensity would rise to 1.2 kg of CO_2 equivalent per kg of hydrogen. If the source gas contained less hydrogen, it would be 1.5 kg of CO_2 equivalent per kg of hydrogen, while an unproductive well could be as high as 16.1 (*Joule*, doi.org/kmpx).

Comparing this with other sources is tricky because different methods and assumptions result in widely varying estimates. But one recent study concluded that hydrogen from natural gas has a carbon intensity of 71 to 82 kg CO_2 equivalent per kg of hydrogen. For blue hydrogen it was 15 to 53, and for green hydrogen it was 3 to 13.

Another study by Kiane de Kleijne at Radboud University in the Netherlands estimated that the carbon intensity of green hydrogen is between 0.4 and 17 kg CO_2 equivalent per kg of hydrogen.

So if Brandt's estimates are correct, geologic hydrogen could be the greenest source of all. "I think it is good news," he says.

Leaky molecule

But Robert Howarth at Cornell University in New York isn't convinced that geologic hydrogen will result in lower greenhouse gas emissions than green hydrogen. He thinks the study underestimates the warming effect for several reasons – for instance, a paper published last month concluded that the warming effect of hydrogen is much higher than previously thought.

Assumptions about leakage are also critical, says Howarth. "Hydrogen is the smallest molecule in the universe, and so we would expect it to be very, very leaky. The more the gas is handled, stored and transported, the greater the emissions will be and the worse the greenhouse gas consequences."

"My take-home is that the greenhouse gas footprint of geological hydrogen remains poorly known because we do not know what to expect for hydrogen emissions," he says.

One big advantage geologic hydrogen has over green hydrogen is that it doesn't require renewable energy, meaning this energy remains available for other things. However, we need to slash emissions by 2050 and it isn't clear if any significant quantity of geologic hydrogen can be produced by then, says de Kleijne.

"I don't think it should be considered a replacement of other ways of producing hydrogen with lower emissions that are in much further stages of technological development," she says. ▮

Health

How cancer-fighting immune cells could be made safer and more powerful

Michael Le Page

AN IMPROVED way of engineering immune cells to fight cancers and other conditions could make them safer and more effective. It would also allow doctors to pause the treatment if side effects are bad.

"It could give an extra level of control over the systems," says Jason Lohmueller at the University of Pittsburgh, Pennsylvania.

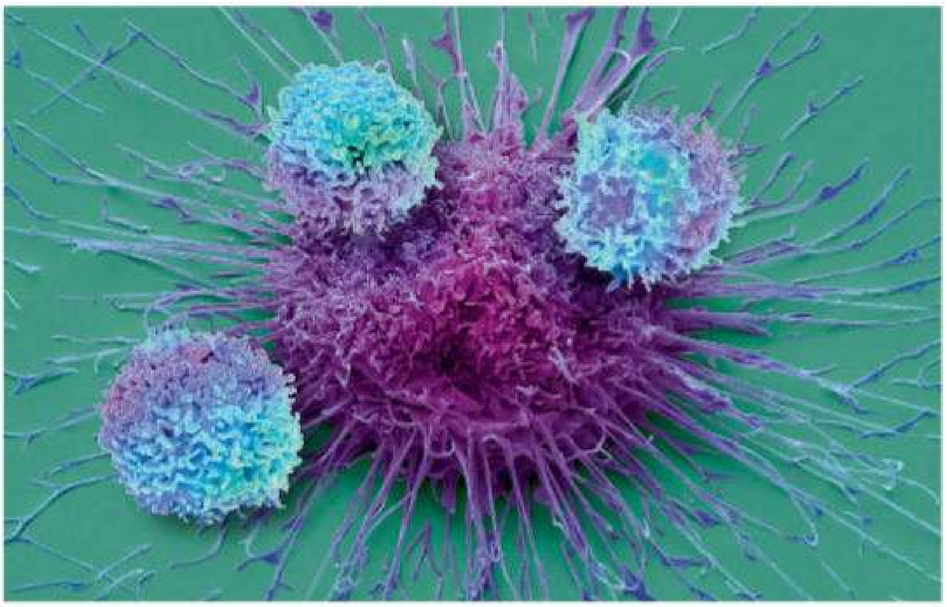
CAR T-cells are immune cells that are genetically engineered to attack specific targets in people's bodies. They seem highly effective against leukaemia, with several treatments already approved.

Recent results have shown CAR T-cells could help treat conditions other than cancer. For instance, last year it was reported that five people with the autoimmune condition lupus were successfully treated with them.

CAR T-cells are created by extracting immune cells from a person's blood and using a virus to add a gene. This gene encodes a receptor that protrudes from the outside of the cell and binds to a specific protein. When the receptor binds to its target – usually a protein found on the outside of cancer cells – it sends an attack signal, triggering the CAR T-cell to kill the cell it is bound to.

But about 80 per cent of people on CAR T-cell therapies have severe side effects. One reason why is that it is hard to find proteins specific to cancer cells, so CAR T-cells may attack healthy cells that have the target protein. Attacking T-cells also release signals to summon help, and this can trigger a life-threatening immune reaction known as a cytokine storm.

T-cells around a lung cancer cell, as seen by an electron microscope



STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

To address this risk, Lohmueller and his colleagues are using proteins called adapters. In this approach, the receptor doesn't bind directly to the target protein. Instead, it has a slot for an adapter, which binds to the target protein. The adapter can be injected in several doses after the CAR T-cells have established in the body, and the doses can be paused if there are side effects.

Lohmueller's team has created adapters that have an "off" switch. These adapters can be chemically altered by a drug so they no longer fit the receptor slot. If someone gets bad side effects, injecting the drug should stop the CAR T-cells attacking (bioRxiv, doi.org/gr9ntz).

So far, this approach has only been tested on cells in the lab, but the experiments show it can also be used to stop CAR T-cells attacking one target protein while continuing to attack another. This would allow doctors to safely test new therapies, says Lohmueller.

Some groups have created CAR T-cells with kill switches, but killing the cells stops treatment entirely. With the team's approach, the CAR T-cells can be reactivated again by injecting another dose of adapters, says Lohmueller.

His team is also developing adapter "on" switches so CAR T-cells bind to the target protein only in specific environments, such as those low in oxygen or highly acidic. These conditions are found in many solid tumours, so such CAR T-cells should be better at targeting cancerous cells. ▮

Infectious diseases

People pass swine flu to pigs more than the other way round

HUMANS have passed swine flu to pigs at least 370 times over 12 years in the US. Understanding how the virus behind the disease moves between people and pigs could help us reduce infections.

Swine flu is the common name for a condition that originated in pigs. It is caused by a type of influenza A, known as H1N1, of which a variant called pdm09 led to an outbreak in people in 2009. Since then, the variant has lingered in pigs and infected some people.

Tavis Anderson at the US Department of Agriculture and his colleagues wanted to investigate how pdm09 has spread. They analysed genetic sequences of all the H1N1 virus samples collected in people and pigs in the US between 2009 and 2021. Of these, 12,823 human and 1112 swine samples were of the pdm09 strain.

To assess which of these samples were the result of transmission between the two species, the researchers looked at how similar the samples were to each other. If one version of the virus in a person looked reasonably different to versions in other people, they assumed it was passed by a pig. Conversely, if a version of the virus in a pig looked different to those in other pigs, they assumed it was passed by a person.

From this, they estimated there were 370 cases of human-to-swine transmission and 17 cases of swine-to-human transmission over the 12 years, most probably occurring due to farming (*PLoS Pathogens*, doi.org/kmpq). However, the true number may be higher as not all infections lead to ill health or are reported, says Anderson.

370

Estimated cases of people passing swine flu to pigs in the US in 12 years

Between 2020 and 2021, during the height of the covid-19 pandemic, cases of pdm09 fell in people, which suggests it is possible to reduce the interspecies transmission of swine flu if proper control measures are taken, says Rebecca Jane Cox Brokstad at the University of Bergen, Norway. ▮

Chen Ly

Computing

Mathematicians find 27 tickets that guarantee UK National Lottery win

Matthew Sparkes

YOU can guarantee a win in every draw of the UK National Lottery by buying just 27 tickets, say a pair of mathematicians – but you won't necessarily make a profit.

Players of the UK "Lotto" choose six numbers from 1 to 59, paying £2 per ticket. Prizes are awarded for tickets matching two or more of six randomly drawn numbers.

David Cushing and David Stewart at the University of Manchester, UK, claim that despite there being 45,057,474 combinations of numbers, it is possible to guarantee a win with just 27 specific tickets.

The proof of their idea relies on a field called finite geometry and involves placing each of the numbers from 1 to 59 in pairs or triplets on a point within one of five geometrical shapes, then using these to generate lottery tickets based on the lines within the shapes. The five shapes offer 27 such lines, meaning that 27 tickets bought using those numbers, at a cost of £54, will hit every possible winning combination of two numbers (arXiv, doi.org/kmcw).

The 27 tickets that are claimed to ensure you will win at least some prize

1, 2, 3, 4, 5, 6

1, 2, 3, 4, 7, 8

1, 2, 5, 6, 7, 8

9, 10, 11, 12, 13, 14

9, 10, 11, 15, 16, 17

12, 13, 14, 15, 16, 17

18, 19, 20, 21, 26, 27

18, 19, 22, 23, 30, 31

18, 19, 24, 25, 28, 29

20, 21, 22, 23, 28, 29

20, 21, 24, 25, 30, 31

22, 23, 24, 25, 26, 27

26, 27, 28, 29, 30, 31

32, 33, 34, 35, 40, 41

32, 33, 36, 37, 44, 45

32, 33, 38, 39, 42, 43

34, 35, 36, 37, 42, 43

34, 35, 38, 39, 44, 45

36, 37, 38, 39, 40, 41

40, 41, 42, 43, 44, 45

46, 47, 48, 49, 54, 55

46, 47, 50, 51, 58, 59

46, 47, 52, 53, 56, 57

48, 49, 50, 51, 56, 57

48, 49, 52, 53, 58, 59

50, 51, 52, 53, 54, 55

54, 55, 56, 57, 58, 59

The work yielded a specific list of 27 tickets, but the pair say subsequent work shows there are two other combinations of 27 tickets that also guarantee a win.

Looking at the winning numbers from the 21 June Lotto draw, the pair found their method would have won £1810. But the same numbers played on 1 July would have matched just two balls on three of the tickets – still a technical win, but giving just three "lucky dip" tries in the next draw, each of which came to nothing.

Stewart says proving that 27 tickets could guarantee a win was relatively easy, but proving it is impossible to guarantee a win with 26 was far trickier. He estimates that the number of calculations needed to verify that would be 10^{165}, far more than the number of atoms in the universe.

The solution was a computer programming language called Prolog. Unlike conventional computer languages where a coder sets out what a machine should do, step by step, Prolog takes a list of facts relating to a problem and whittles down an array of possible solutions.

Cushing says the work shouldn't be taken as a reason to gamble, particularly as it doesn't guarantee a profit, but hopes it encourages mathematicians to use Prolog.

"Subsequent work shows there are two other combinations of 27 tickets that also guarantee a win"

A spokesperson for Camelot, the company that operates the lottery, said the paper made "interesting reading". "Our approach has always been to have lots of people playing a little, with players individually spending small amounts on our games," they say. "It's also important to bear in mind that, ultimately, Lotto is a lottery. Like all other National Lottery draw-based games, all of the winning Lotto numbers are chosen at random – any one number has the same and equal chance of being drawn as any other, and every line of numbers entered into a draw has the same and equal chance of winning." ▮

Materials

Supersonic cracks seem to be breaking the laws of physics

THIN strips of a porous gel have been found to crack impossibly quickly.

"What we found was a total surprise. This just isn't supposed to happen," says Jay Fineberg at the Hebrew University of Jerusalem in Israel. The finding could improve our understanding of some earthquakes and how brittle materials break.

Fineberg and his colleagues used fast, high-resolution cameras to record how cracks spread through thin samples of porous gels that are used for analysing molecules in medical labs. For each sample, they printed a grid of tiny squares on the gel to more easily visualise where the cracks were, and they made a shallow notch where they wanted the gel to crack when stretched.

Then, they stretched the gel and recorded how the tip of the crack propagated. Across many recordings, these cracks moved unexpectedly quickly. The fastest were about 30 per cent faster than the speed of sound. Even when the researchers skipped the notch-making step, some still travelled 15 per cent faster than the speed of sound (*Science*, doi.org/kmcv).

Fineberg says theoretical and experimental studies of materials that crack have so far shown that cracks can't propagate faster than sound. This is because the speed of sound reflects how quickly mechanical energy can move from one part of the material to another, which must happen for it to crack.

For common stretchy objects like springs, the relationship between the force that stretches them and how much they elongate is simple and direct, but that is not the case for every part of these gels, says Alain Karma at Northeastern University in Massachusetts, who wasn't involved in the work.

"It's really puzzling how you could bring energy to the crack fast enough for this behaviour"

"There is no theory that really describes how a crack propagates at a very high speed in this kind of elastic medium. And it's really puzzling how you could bring energy to the crack fast enough for this behaviour," he says.

Resolving this puzzle could help us understand dangerous events that involve fractures like earthquakes, where some cracks propagate very quickly. ▮

Karmela Padavic-Callaghan

Ageing

Young blood extends lives of mice

Old mice that are surgically attached to young ones have now been shown to live longer, as well as having their organs rejuvenated, discovers **Alice Klein**

SURGICALLY attaching old mice to young mice for three months turns back the biological age of the older individuals and extends their lifespan after they are detached. The finding adds to a large body of research pointing to the restorative effects of young blood.

Several studies have found that sewing old and young mice together so their blood flows into each other's bodies – a procedure called parabiosis – has rejuvenating effects on the older individual's brain, liver and muscles. However, whether this means they end up living longer, even after separation from the young mice, has been unclear.

To find out, a team co-led by James White at Duke University in North Carolina and Vadim Gladyshev at Harvard University surgically connected old mice (aged 20 months) to either young mice (aged 3 months) or other old mice for a period of three months. The researchers then detached them and measured how long they lived. "We wanted to know, 'do the anti-ageing effects just go away after you take the mice apart?'," says White.

Six more weeks

The old mice that had been joined to the young mice ended up living six weeks longer, on average, than those that had been joined to other old mice, a lifespan extension of about 5 per cent. "If you could improve human lifespan by 5 per cent, that could mean an extra four or five years," says White. However, the effect is smaller than that achieved by calorie restriction, which can make mice live up to 27 per cent longer.

The researchers didn't compare these mice's lifespans with those that weren't surgically attached to any other animal in case the procedure itself affected their longevity, which could blur the results.

SHUTTERSTOCK/IGOR STRAMYK

Experiments in mice have shown that being attached to a young mouse can rejuvenate an older animal

The team also used epigenetic clocks, which analyse patterns of markers on DNA called methyl groups that correlate with age, to find out whether the old mice that were connected to young mice became biologically "younger". Indeed, straight after detachment and even two months later, they appeared up to 30 per cent younger than those that had been joined to old mice.

What's more, the old mice that were previously paired with young mice displayed altered gene expressions, including higher expression of certain metabolism genes and reduced expression of inflammation genes, which was similarly observed in mice that underwent calorie restriction (*Nature Aging*, doi.org/kmcs).

The reason for these anti-ageing effects may be that the blood of young mice contains cells, proteins or other components that have rejuvenating properties when they flow into old mice, says White. Another possibility is that the blood of the old mice gets filtered or diluted through the healthier kidneys and livers of the young mice, helping to remove harmful components associated with ageing, he says.

Small human trials

Some preliminary studies have investigated whether blood transfusions from young people reverse ageing in older people. For example, Ambrosia, a US start-up, gave blood plasma from donors aged 16 to 25 to people aged 35 or older. It then compared age-related biomarkers in the older people from before and after the infusion. But the results were never made public and the company folded.

BRYAN JOHNSON/MAGDALENA WOSINSKA

US tech entrepreneur Bryan Johnson has tried transfusions of plasma

Another small trial gave weekly injections of young plasma to people with Alzheimer's disease and found minimal benefits. And earlier this month, entrepreneur Bryan Johnson (pictured below), aged 45, reported no benefits from receiving plasma transfusions from his 17-year-old son.

These disappointing results may have occurred because plasma only contains the liquid portion of blood, without any cells, and the frequency of treatment may not have been optimal, says White. "The reason the parabiosis effect is so strong is probably because there's constant exposure to all components of young blood."

David Irving at Australian Red Cross Lifeblood, which collects and distributes donated blood products across the country, believes that using blood to try to extend lifespan is unethical because it "diverts a precious and often life-saving resource away from cancer patients and others in need".

"A better focus would be on calorie restriction, for which there is much better evidence," he says.

Several groups are now trying to pinpoint the precise rejuvenating components in young blood so that they could potentially be made in a lab, without the need for blood donors, says White. Even if these efforts don't succeed, the latest study adds to growing evidence that the negative health effects of ageing aren't as inevitable as we once thought, he says. "It does show that ageing can be manipulated and it's not simply a fact of time." ▮

Environment

Start of spring in the Arctic is increasingly unpredictable

Chen Ly

THE timing of spring in the Arctic has become more and more erratic in the past 25 years, increasing discrepancies between the behaviour of animals and plants and the conditions they depend on.

Since 1996, Niels Schmidt at Aarhus University in Denmark and his colleagues have been monitoring the ecosystem at Zackenberg, a mountain in north-east Greenland.

"It is one of the most beautiful places on Earth," says Schmidt. "It's in the world's largest national park, which means that it's a very pristine environment."

To track spring's annual arrival in the region, the team recorded the dates of events such as when plants flowered, birds began breeding and insects and spiders emerged from hibernation.

2 weeks

Springtails left hibernation this much earlier in 2020 than 1996

In 2007, the team published the results from the first decade of its observations and revealed that spring was arriving about two weeks earlier in 2005 than in 1996. If that trend continued, spring would eventually extend well into the months we think of as winter. "That's not realistic," says team member Tomas Roslin at the University of Helsinki, Finland. "So, we really wanted to see what's happened over a longer period of time."

Now, the researchers have extended their data set by 15 years to cover up until 2020.

NIELS MARTIN SCHMIDT

The onset of flowering varies hugely from year to year in the high Arctic

Instead of spring behaviours appearing ever earlier, they found that the start of the season varied across species. Small arthropods called springtails, for example, woke from hibernation about two weeks earlier in 2020 than in 1996, but Arctic willow (*Salix arctica*) bloomed eight days later (*Current Biology*, doi.org/kmck).

Over the past three decades, north-east Greenland has largely seen rising temperatures and declining snow cover. However, in recent years, snow cover and temperature have fluctuated radically from year to year. "What we have now is a generally warmer climate, but much more variable in terms of temperature and snow conditions," says Schmidt.

JEROEN RENEERKENS

A sanderling incubating four eggs in the Arctic

The findings indicate that Arctic wildlife is gradually becoming out of sync with the climate. "Plants are flowering in one period and the pollinators are flying in a different period," says Schmidt. If this pattern continues, then both groups may decline, which could affect the entire ecosystem. Plants rely on pollinators to reproduce, and pollinators, such as butterflies, rely on the pollen and nectar from flowering plants for food.

"Then the question becomes whether those flowers will find other pollinators, and if the pollinators will find another food source," says Amanda Gallinat at Colby College, Maine.

"This study shows that ecological adjustments to changes in temperature and timing of snow melt are not just linear," says Bart Nolet at the Netherlands Institute of Ecology. "This means it will be hard to predict how these Arctic ecological communities will change with ongoing climate change." ▮

Technology

Metallic shirt could let medical implants communicate

Alex Wilkins

MEDICAL implants could be made to communicate more easily thanks to a shirt woven with bands of metal textiles that act as data channels.

Some implants benefit from measurements taken elsewhere in the body, such as glucose monitoring sensors worn by people who are diabetic that trigger insulin pumps near the pancreas, but connecting them wirelessly is difficult. Signals transmitted inside the body are quickly absorbed and can't travel far, while relay systems outside the body add more hardware that needs charging.

Now, Selman Kurt at the National University of Singapore and his colleagues have designed a nickel and copper strip that can transmit the wireless signals from one implant to another across its surface, increasing the efficiency of the transmission by 1000 times compared with just sending it through the body.

The strip consists of two circles, one for receiving and another for transmitting, connected by a strip of repeating rectangles. The size of the rectangles is tailored to the wavelength of the implant signal, confining it to the surface a bit like an optic fibre encloses light rays.

Kurt and his team tested the strip on the skin of a live pig, successfully connecting a heartbeat monitor and nerve stimulator 40 centimetres apart (*Nature Communications*, doi.org/kmcq).

The fabric isn't suitable for applications needing a continuous connection, though, because the wearer will sometimes need to remove their shirt, says Kurt.

"Compared to normal implant-to-implant communication, this technique can increase the received signal by three orders of magnitude of receive signal – that's a really good thing," says Muhammad Qamar at Queen Mary, University of London. ▮

Anthropology

Ancient make-up found in tomb

Residues found in a 2000-year-old tomb in China hint that use of cosmetics was widespread

Carolyn Wilke

ORDINARY people in China may have been augmenting their looks with make-up some 2000 years ago. An analysis of two residues found with a grooming kit in the tomb of a woman from the Han dynasty hints that there was a sophisticated cosmetics industry at the time.

Ancient texts provide a wealth of records on the lives of regular people from later dynasties, including on the composition and cost of cosmetics, says Meng Wu at Shandong University in China. But little information of that type remains about commoners living 2000 years ago or earlier.

Wu and her colleagues found the make-up near the head of a woman buried in a tomb in Jinan, China, along with a mirror. She isn't thought to have been noble because she was only buried with a few objects.

"This discovery is very precious," says team member Zhongming Tang, also at Shandong University. This is because beauty treatments and the decaying boxes they are often found in can easily be mistaken for dirt, he says.

Using a suite of analytical tools, the researchers investigated the chemical composition of the two powders and found hints of their ingredients. One, found beneath the mirror, was a mineral known as lead white that the team suspects was used to make skin fairer.

The other, which was in a lacquer box, would have been close to the skin colour of most people living in that area and may have been used to conceal scars or blemishes.

A mural from Zhengzhou, China, depicting women from the Han dynasty

ANCIENT CHINESE ARTISTS OF THE LATE EASTERN HAN PERIOD

Although it was made of cheap ingredients – animal fat, plant extracts and the silicate mineral mica – the concealer probably took a lot of work to manufacture, says Wu.

The size of the mica particles, which is around the same as those of mica used in cosmetics today, suggests the mineral was ground and filtered to achieve a small and uniform size that would have stuck to skin (*Archaeological and Anthropological Sciences*, doi.org/kk9n).

"Collecting the raw materials, grinding the mica powder, refining the fat, extracting the plant and making the lacquer vessel all took a long time in an age before modern machinery," says Wu. That suggests there was an industry dedicated to making these materials, which would otherwise have been too costly for ordinary people.

Ancient cosmetics have been found in the tombs of aristocratic men and women, but the few examples of non-elites having cosmetics that Wu knows of have all been women.

These findings provide new clues about the lives of ancient people, says Yimin Yang at the University of Chinese Academy of Sciences in Beijing. Yang's work has found that more expensive ingredients were used for elites' cosmetics at the same time. From this study, it appears cosmetics were also popular with people who weren't nobles, but who may have been wealthy, he says. ▮

Astronomy

Water vapour spotted in young planetary system

THE James Webb Space Telescope (JWST) has allowed astronomers to spot water vapour in a young planetary system, in the same area where rocky exoplanets may be forming. This means it is possible Earth formed with water bound within it, rather than being dry and having its water delivered later.

PDS 70 is a star about 400 light years away that is encircled by two huge discs of gas, separated by a gap of 8 billion kilometres. The outer disc is home to at least two young planets, each several times larger than Jupiter, and the inner disc contains the rocky materials necessary to form more planets.

Giulia Perotti at the Max Planck Institute for Astronomy in Germany and her colleagues have found signs of water in the inner disc of the PDS 70 system using JWST. Previous observations of similar discs found no water, and water wasn't expected to survive the intense radiation so close to a star. But it has survived for millions of years near PDS 70, at temperatures upwards of 300°C, probably due to shielding from other particles in the area (*Nature*, doi.org/kmb7).

The fact that it has survived means that if any Earth-like planets do form in the inner disc, they will incorporate that water. There is a long-standing debate on whether rocky planets form wet or have their water delivered by asteroids later on, and this is a strong point in favour of the former argument.

"By observing the PDS 70 system, we can trace back how the planets in our solar system formed"

"PDS 70 is a star similar to our sun, just younger and cooler," says Perotti. "By observing it, we can trace back how the planets in our solar system formed and what was their chemical composition before they were fully formed."

Perotti and her team are now making more observations of the inner disc in an effort to identify all its contents – the ingredients for whatever planets might form there in the future. This could shed some light on how rocky worlds like Earth form, and what exactly they are made of at the very beginning. ▮

Leah Crane

Health

Daily aspirin raises risk of brain bleeds for little benefit

Christa Lesté-Lasserre

TAKING a low dose of aspirin every day doesn't prevent the most common type of stroke among older people who have never had such an event, and may raise the risk of a dangerous brain bleed.

As we age, our chance of having blood clots grows, which can block blood flow to the brain and trigger an ischaemic stroke. Attempting to counter that risk, doctors sometimes prescribe older people 75 to 100 milligrams of aspirin daily – generally considered a low dose – as the drug thins the blood.

John McNeil at Monash University in Melbourne, Australia, and his colleagues have investigated the incidence of strokes and internal head bleeds in 19,114 people over an average of nearly five years. At the start of the study, participants were all aged 65 or older and none had a history of a stroke or other cardiovascular conditions.

About half the people took 100 milligrams of aspirin a day, while the others took a placebo. Among those taking low-dose aspirin, 1.5 per cent experienced an ischaemic stroke during the study period, compared with 1.7 per cent in the placebo group. Taking into account the number of years each person was involved in the study, the team found aspirin didn't reduce the risk of an ischaemic stroke.

What's more, 1.1 per cent of the people who took aspirin had bleeding inside or around their brain, compared with 0.8 per cent of those taking a placebo. These bleeds sometimes occurred after a blow to the head, such as from a fall, but were sometimes spontaneous (*JAMA Network Open*, doi.org/kk9j).

"This is just more evidence that prescribing aspirin to people who don't need it is not a great idea," says McNeil. ▮

Always consult your doctor before taking or changing medications

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Environment

Building with wood may not be as climate-friendly as thought

James Dinneen

USING more wood for construction has been touted as a lower-emission alternative to building with steel and concrete, but it may not be as carbon-friendly as thought.

"It would be very convenient if wood were a better solution," says Tim Searchinger at Princeton University. Wood is, in theory, a renewable resource and any used in buildings acts as long-term carbon storage.

> "Over a long enough time, you cut emissions, but in the interim you've increased warming"

Research has found that using wood for construction instead of concrete and steel can reduce emissions.

But Searchinger says many of these studies are based on the false premise that harvesting wood is carbon neutral. "Only a small percentage of the wood gets into a timber product, and a fraction of that gets into a timber product that can replace concrete and steel in a building," he says. Efficiencies vary in different countries, but large amounts of a harvested tree are left to decompose, used in short-lived products like paper or burned for energy, all of which generate emissions.

Many of those emissions may eventually be recaptured if more trees are planted. But Searchinger says that doesn't fly given that we need carbon dioxide out of the atmosphere now. "Over a long enough period of time, you get a greenhouse gas reduction," he says. "But in the interim you've increased warming."

In a report for the World Resources Institute, Searchinger and his colleagues have modelled how using more wood for construction would affect emissions between 2010 and 2050, accounting for the emissions from harvesting the wood. They considered various types of forests and fractions of wood going towards construction. They also factored in the emissions savings from replacing concrete and steel.

In some scenarios, the researchers found significant emissions reductions. But each case required what they considered an unrealistically high portion of the wood going towards construction, as well as rapid growth only seen in warmer places, like Brazil.

In general, they found a large increase in global demand for wood would probably lead to rising emissions for decades. Accounting for emissions in this way, the researchers report in a related paper that increasing forest harvests between 2010 and 2050 would add emissions equivalent to roughly 10 per cent of total annual emissions (*Nature*, doi.org/gsh6d5).

William Moomaw at Tufts University in Massachusetts says the works shows that harvesting timber, even when done sustainably, isn't a carbon-neutral activity.

But Stephen Prisley at the National Council for Air and Stream Improvement, a US-based non-profit group that conducts research for the forestry industry, is sceptical of many of the conclusions in the report. "It seems like some of the assumptions in emissions deliberately err on the side of making forest harvest look less desirable," he says. However, he says it is possible the forest-products industry has overstated the emissions benefits of using more wood.

Ali Amiri at Aalto University in Finland says the report's conclusions about emissions from rising demand are probably correct, but the story is different for wood we already harvest. Boosting the efficiency of current harvests and using more wood for longer-lived purposes than paper would cut emissions, he says. "We cannot just say we should stop using wood." ▮

Wood is often proposed as a lower-emission material for building

LESZEK GLASNER/SHUTTERSTOCK

Astronomy

Gas gives stars an innate twinkle

STARS have an innate twinkle that comes from gas rippling from their core to the surface.

From Earth, stars seem to twinkle because the atmosphere bends and fragments their light before it gets to our eyes, but they also change over months.

Evan Anders at Northwestern University in Illinois and his colleagues have used a computer model to create the first 3D simulation of this pattern, which comes from rippling waves created by the churning and mixing of hot and cold gases. These can slightly change the star's temperature and, as a result, its brightness.

The researchers found that the bigger and brighter the star is, the larger the waves, and so the more it twinkles (*Nature Astronomy*, doi.org/kmcc). **Sofia Quaglia**

Health

Legalisation hikes cannabis poisonings

CASES of cannabis poisoning have increased following the drug's legalisation, an analysis of 30 studies from the US, Canada and Thailand has found.

Most people with cannabis poisoning aren't at risk of dying, but in serious cases, too much cannabis can lead to trouble walking, talking and breathing. Tetrahydrocannabinol (THC), the major psychoactive component of cannabis that gets users high, can also lead to abnormal heart rhythms, comas and seizures.

The results showed that after marijuana legalisation occurred, on average, the risk of cannabis poisoning more than doubled for people of all ages and quadrupled for children (*Addiction*, doi.org/kmcd). Children typically ingest the drug through gummies and other foods laced with it. **Corryn Wetzel**

SHUTTERSTOCK/REPTILES4ALL

Zoology

Lizards put less effort into courting when it gets hot

SPINY lava lizards spend less time wooing and choose partners more hastily in hotter temperatures.

Nicola Rossi at the National University of Córdoba in Argentina and his colleagues wondered if spiny lava lizards (*Tropidurus spinulosus*) change their courting behaviour to cope with increasing heat. "They do push-ups around the rocks they guard to signal their ability," says Rossi. "It requires a lot of energy." The lizards also bob their heads to attract mates.

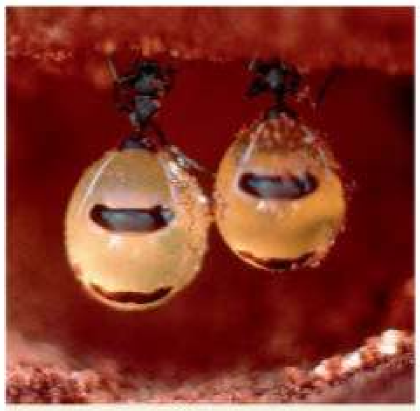
The researchers studied lizards from two nearby areas of a nature preserve in Argentina. One group lives on a sunny, rocky outcrop with an average temperature of 30°C (86°F), the other in a zone with lots of shady trees that was about 26.5°C (80°F) on average.

The reptiles in the warmer area were less active during the hottest midday hours. Next, the researchers brought 42 male and 35 female lizards into the lab and gave them their choice of two mates behind a glass barrier. Some lizards were in their normal climate, while others were in environments 2 or 4°C warmer than usual.

Male lizards did just as many push-ups regardless of temperature, but while some kept bobbing their heads when it got hotter, others gave up.

Females of this species typically opt for males with the most colourful flanks, but at the highest temperature, their preference vanished (*PLoS One*, doi.org/kmcb). "If they are choosing their mates randomly, they're not choosing the best males," says Rossi. Females also did fewer head bobs when it was hotter. This could affect how well the species adapts to climate change. **CW**

Really brief



MINDEN PICTURES/ALAMY

Ant honey kills common bacterium

Australian honeypot ants (*Camponotus inflatus*) make honey with antimicrobial properties. The ant colonies include workers that store the honey in their abdomens (pictured). A water solution made up of 8 per cent honey killed the bacterium *Staphylococcus aureus* (*PeerJ*, doi.org/kmcf).

Cuckoos foiled by unique egg patterns

Fork-tailed drongos (*Dicrurus adsimilis*) produce individualised patterns on their eggs, which seem to help them recognise their own ones and reject 94 per cent of the ones African cuckoos (*Cuculus gularis*) lay in their nests (*Proceedings of the Royal Society B*, doi.org/kmcg).

Fungi break down common plastic

A type of fungi that decays hardwood trees has been found to break down polyethylene, a plastic used in shopping bags. The fungi, found in hardwood in Sri Lanka, reduced the weight of low-density polyethylene, whether or not wood was present (*PLoS One*, doi.org/gsh97r).

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8 September 2023 | 3 days | £749

Science of the Jurassic Coast: Dorset and Devon

Explore the Jurassic Coast, where geology takes centre stage. It is the only place on Earth where rocks from the Triassic, Jurassic and Cretaceous periods can be seen in one place, representing 185 million years of the planet's history.

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29 September | 3 days | £959

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Explore the mysteries of the universe in an exciting programme that includes an excursion to UNESCO World Heritage site Jodrell Bank to see the iconic Lovell telescope.

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The columnist
Annalee Newitz on the rise of automated AI content p21

Aperture
The Endeavour space shuttle is prepped for display p24

Letters
There is no easy way to tackle the obesity epidemic p26

Culture
A new book spurs a conversation about conversation p28

Culture columnist
Bethan Ackerley has faith in *Foundation*'s higher plan p30

Comment

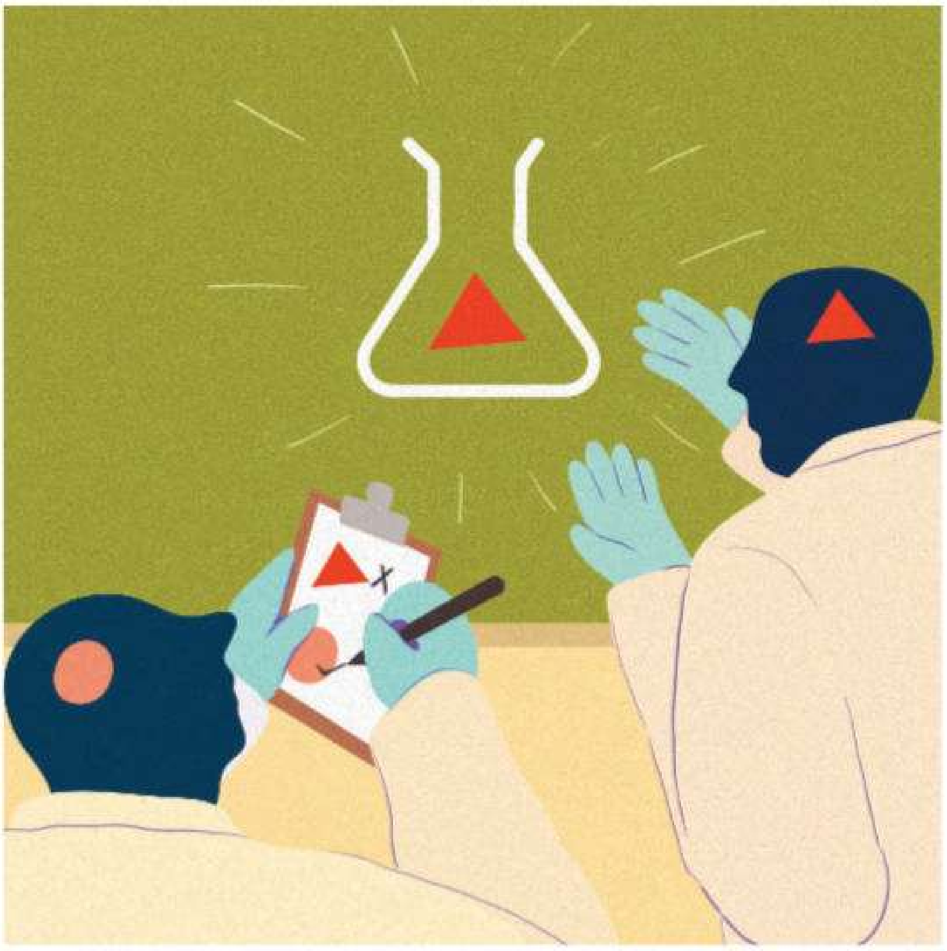
A question of bias

Even when faced with hard evidence, why did whole scientific communities reject world-changing hypotheses, asks **Dan Levitt**

A HUNDRED years ago, scientists were sure of many truths. The greatest experts were certain that the universe had always existed and was always the size it is now. Most biologists were sure that proteins, not DNA, were responsible for heredity. Biochemists believed that, outside the nucleus, the interior of a human cell contained little more than busy enzymes – a "biochemical bog" that carried out all the reactions that are essential to life. These sureties were all wrong. Yet scientists reacted to challenges to their accepted truths with dismissal and scepticism.

I began to see how common this knee-jerk reaction was as I researched my book on how scientists reconstructed the journey of our body's atoms from the big bang to now. So many theories that we now consider great breakthroughs were at first waved off, like annoying gnats. Why? We all know that some researchers are territorial, or fear a new theory will undercut their work. But why did entire communities of scientists reject groundbreaking ideas – even those backed by sound evidence?

Puzzled, I tried to categorise the reasons why and found six cognitive biases that arose so often I gave them nicknames. For instance, the "Too Weird to be True" bias led Albert Einstein to initially reject Georges Lemaître's theory of the big bang. The "As An Expert, I've Lost Sight Of How Much Is Still Unknown" bias convinced scientists that organic molecules couldn't exist in space – until Charles Townes proved them wrong. The "You Look For and See the Evidence That Matches Your Existing Theory" bias (commonly known as confirmation bias) impeded our understanding of diseases like scurvy and beriberi, which were killing millions. Scientists tried to explain these illnesses with the ancient Greek theory of humors, then germ theory, before arriving at the concept of vitamin deficiency.


MICHELLE D'URBANO

How could so many brilliant scientists have been so ignorant? If you look a little deeper, you will find that none of us is immune. A Microsoft executive once said: "There's no chance that the iPhone is going to get market share." Just the other day, I was sure that my missing keys couldn't be in my desk drawer because I would never put them there. When covid-19 struck, we all thought we would be back at work in just a few weeks.

But cognitive biases aren't simply weaknesses that trip us up. They are also strengths. As psychologists Daniel Kahneman and Amos Tversky have shown, our brains are crammed with biases. Many are there for a reason: we couldn't survive without them. We have to make assumptions in order to live. We would be paralysed if we constantly questioned whether the sun will rise tomorrow. Often, ideas that seem too weird to be true are, in fact, too weird to be true. Unconscious assumptions offer us shortcuts that allow us to avoid constantly rethinking everything.

We will never be entirely rid of biases. That is why even scientists, who pride themselves on carefully interpreting evidence, are prone to them. Biases are part of the human condition, and scientists need to be aware their brains are full of them. As those I profiled discovered, our cells are crammed, not just with enzymes, but with a mind-boggling assortment of molecular machines. DNA, not protein, is the molecule responsible for heredity. And the universe was once contained in a tiny point of space and time.

All kinds of things are possible that we would never expect. That is the beauty of life. The history of scientific innovation encourages us to remain humble, examine evidence with an open mind and try to see the world not as we would like it to be, but – to the extent that we can – as it truly is. Understanding this helps us to appreciate the amazing world we live in. ▮

Dan Levitt is the author of *What's Gotten Into You: The story of your body's atoms, from the big bang through last night's dinner*

This changes everything

On strike against AI

The threat of artificial intelligence-authored content hangs over many creative industries. Actors and writers need to push back against automation, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Terraformers* and they are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading
We Need New Stories, *a fantastic analysis of political myth-making in the media by Nesrine Malik.*

What I'm watching
Polite Society, *the wild tale of a teenage wannabe stuntwoman from Nida Manzoor.*

What I'm working on
Growing chamomile and mint in my garden to make tisane.

This column appears monthly

ONCE upon a time, way back in the innocent year 2008, I founded a blog about science and science fiction called io9. It was a fun job, where I worked with eight or so full-time writers who were, as far as I know, completely human. After I moved on, io9 continued to thrive under the stewardship of some fine biological entities – until last month. That's when I opened the site to discover one of the most terrible posts ever written, entitled simply "A chronological list of *Star Wars* movies & TV shows". Reader, it was neither chronological nor was it a complete list. It was, of course, written by artificial intelligence.

I wasn't the only person pissed off by this development. io9 deputy editor James Whitbrook – who wasn't consulted before the article was posted – wrote an outraged letter to io9 parent company G/O Media, detailing every mistake in the poorly written blob of text. The AI incursion blew up into big news, covered everywhere from *The Washington Post* to Hollywood trade publication *Variety*. For its part, G/O Media claimed this was just a start, then noted ominously that, next time, the AI would write a better article.

The story was such big news because the threat of AI-authored content hangs over many creative industries right now. The Writers Guild of America (WGA) is currently on strike in part because the labour union wants a contract that guarantees AI won't be given writing credits for screenplays. The Screen Actors Guild and the American Federation of Television and Radio Artists (SAG-AFTRA) joined the strike because some movie studios have started replacing actors with digital replicas. In one widely reported case, a studio asked actors for digital scans of their bodies and voices to be used "in perpetuity". An actor who took up that offer could be paid for one day of work, while the studio would make a profit from it until the end of time.

I talked to Eric Heisserer, a member of the WGA contract negotiation team, about why AI has become such a big threat now. As the screenwriter of alien-contact movie *Arrival* and showrunner on Netflix fantasy series *Shadow and Bone*, Heisserer is no stranger to speculative scenarios. But AI is no longer the stuff of science fiction. He said that when contract negotiations started earlier this year, AI was barely on anyone's mind at the WGA. But by April, most members had heard enough about AI apps like ChatGPT and Midjourney that they had started to worry.

> **"The science fiction site I founded, io9, is just one of dozens of publications testing out AI, including CNET"**

Then stories started pouring in from people in the industry. One came from an actor who shared "audition sides", scenes used to audition actors for projects where the script is under wraps. Typically, a writer would be paid to make audition sides as part of their job as a screenwriter. But these were entirely written by ChatGPT and the dialogue was hard to read; it was like the "uncanny valley version of writing", said Heisserer.

Another member of the union came forward to say "she had been approached by a producer who [wanted] to hire her for 48 hours to do what they called 'a voice pass' on an AI-generated feature screenplay. They wanted to make it sound human or fix whatever felt off in the dialogue." Not only was it depressing to contemplate a gig making an AI script sound human, but the pay was unacceptable. A job that would normally take months – writing a screenplay – was compressed into two days. Plus, who would get the writing credit? Writers in the union get paid based on screenwriting credits and if an AI takes top billing, then the writer loses.

Another issue that Heisserer thinks studios should be worried about is copyright. Generative AI models like ChatGPT learn to write by consuming and regurgitating text written by human beings. It "could end in a feeding frenzy where work the studio owns is now being legally devoured by a rival studio", he mused. "It's going to be a spaghetti bowl for lawyers figuring out the ownership of material."

Still, AI isn't going away. OpenAI, which created ChatGPT, and Google have been meeting with newspapers in the US and offering to pay them to test out AI for covering local news and doing research. io9 is just one of dozens of companies and publications trialling AI, including CNET. Heisserer thinks that the WGA and SAG-AFTRA strikes are just the beginning. He foresees a need for journalists and novelists to push back on the use of automation in their workplaces too.

I wondered aloud if AI would ever join a union. Heisserer laughed. "AIs are going to join unions long after they become CEOs and executives. There are far trickier elements to being an artist than there are to [executive] decision-making and market analysis." It was the kind of sick burn only a human could come up with. For now. ■

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Ready for take off

California Science Center

DISPLAYING a space shuttle is harder than it may seem – you can't just plunk it down and set up the velvet rope. So, before the shuttle Endeavour (below) can take up residence on its 1600-tonne concrete slab at the California Science Center in Los Angeles, there will be six months of prep.

While the other three shuttles are on show across the US in a horizontal position, Endeavour will be placed in a "ready-to-launch" vertical position, complete with the boosters and tank that would be needed to send it back up to space. Such a stack requires heavy hardware to keep it upright: six seismic isolators to protect it from earthquakes, huge studs made of specialised materials, and some of the strongest cranes out there to stack up the 61 metres of spacecraft.

The first parts lifted in were the aft skirts (one of which is shown in the main image, hanging from the crane), which are the base of the rocket boosters. Next are the boosters, then the enormous fuel tank and, finally, Endeavour itself. The roof of the building will then be built around the shuttle. It won't be time to launch, but it sure will look like it.

Leah Crane

Editor's pick

There is no easy way to tackle the obesity epidemic

15 July, p 32

From Ken Hill, London, UK

Obesity is worryingly omnipresent in some countries and is, in my opinion, unlikely to be significantly abated by the use of drugs. Education and changes in attitude are long, slow roads to correction in society, but are utterly necessary to crack this problem. As demonstrated by the spectacularly unsuccessful dieting route to long-term weight loss, there will be no quick, sustainable fix.

Moon's hot zone could have been nuclear reactor

15 July, p 13

From Jim McHardy, Clydebank, West Dunbartonshire, UK

You report on the mystery of a radioactive zone beneath the moon's surface in the Compton-Belkovitch area.

Evidence of past natural uranium nuclear reactors, moderated by water, has been found in Gabon. On the moon 3.5 billion years ago, when the last eruption of the volcano in that area took place, the amount of uranium-235 would have been greater, meaning a natural nuclear reactor would have been possible.

Water is needed as a moderator in natural uranium reactors and in modern thorium reactors, so if the above is correct, then further evidence is supplied for the presence of water on the moon.

Did I jokingly resolve a big problem in physics?

8 July, p 30

From David Hulme, Stockport, Greater Manchester, UK

I should state right at the outset that I am no physicist. I am a retired journalist and the written and spoken word is my area of expertise. But I read *New Scientist* because I am a science nut.

So, I was amazed when I read Heinrich Päs's feature "Reality reconstructed", particularly the line where he said string theory researchers are suggesting that gravity may be entanglement in disguise. At the end of March, in an email to a friend, I jokingly wrote that gravity could be spooky action at a distance. The text of the email is included below to give you its layman's flavour.

"My take on general relativity [GR] goes thus: if you travel extremely fast, your watch slows down and may even stop. And we have spacetime because it takes time to travel through space. And gravity is spooky action at a distance, not just a distortion of spacetime. I might just have cracked the missing link between GR and quantum physics with that last bit!"

It isn't just AI – new tech is always disruptive

Letters, 15 July

From Robert Willis, Nanaimo, British Columbia, Canada

Almost every new technology has been met with disbelief, dismissal and doomsaying. But I have yet to read a cogent argument that the social impact of AI available now and in the near future will amount to much more than that of the steam loom or computer.

Yes, there will be economic sectors that will see severe disruption: this also happened with electrification and, more recently, with computerisation. In the same way that we need to have a rigorously planned transition to an economy free of fossil fuels, we must develop informed and thoughtful plans for adapting economies to the possibilities that may arise from developments in AI technologies.

To strengthen breathing, just blow into a shawm

1 July, p 40

From Rose Ovenden, Gembrook, Victoria, Australia

I loved "Cheat your way to better health", but when it came to E. Fiona Bailey's experiments with the Powerbreathe device, I wondered if she had considered the breathing exercise provided by playing a wind instrument. Brass and reed instruments in particular demand not only great breath control, but high-intensity "resistance training" for the diaphragm and ab muscles – a lot more than five sets of six breaths, too. As a shawm player, I have personal experience of this.

We have lost touch with our wider microbiome

1 July, p 17

From Will Kemp, Wagait Beach, Northern Territory, Australia

You suggest that industrialisation and diet may influence the human gut microbiome. I suspect that a more important factor is our alienation from nature.

Apparent similarities between the human gut microbiome and that of the soil suggest to me the two are part of the same system. For almost all of human existence, there has been a direct connection between the gut and the soil. Our ancestors would have eaten food without systematically cleaning it, so would have been "contaminated" with soil microbes. Defecation would have returned gut microbes directly to the soil, rather than waste being carried away by modern sewerage systems.

In this way, our gut microbiota would have been constantly refreshed with microbes from the soil and vice versa. This cycle has now been broken, and our gut microbiome is affected by antibiotics and excessive hygiene, without the constant replenishment that contact with soil would bring.

No doubt about it, animals are expressing emotions

8 July, p 34

From Ingrid Newkirk, People for the Ethical Treatment of Animals, Washington DC, US

Your article on animal feelings suggests anthropocentrism could lead us to imbue animals with emotion. When an elephant in a circus screams while being beaten, only a Cartesian would fail to see that she is expressing emotion. So, too, when a cow chases the truck in which her calf is being taken away and when macaques shake the bars of their laboratory cages.

Fear, joy, love, grief and the desire to stay alive aren't human traits, but rather shared ones – or we wouldn't have experiments on animals that depend on acknowledging them. As for farmers considering improving animal welfare, let's just stop eating our fellow Earthlings.

Producing meat in plants seems a much better bet

8 July, p 17

From Keith Walters, Sydney, Australia

I have always believed that genetically engineering plants to produce analogues of animal-sourced protein is going to be far more viable than trying to grow actual animal tissue.

Culturing tissue requires a huge variety of nutrients (many of them currently sourced from animals) and has to be carried out in an ultra-sterile environment.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 9 Derry Street, London, W8 5HY will be delayed

For the record

The tusks of male stink bugs in Tjaltjraak Boodja Park, Australia, are merely unusual (24 June, p 7).

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BigSwim
with GB Swimmer Alice Dearing

STRAVA

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Let's talk it through

Conversation is so essential to our world, yet we take it for granted. Teasing its workings apart makes for a surprising and intriguing read, finds **Tom Tierney**

Book

Talking Heads

Shane O'Mara

Bodley Head

HUMAN conversation is highly structured, and those structures are often consistent across languages. In face-to-face conversation, we tend to take turns speaking for about 2 seconds, with a gap of about one-fifth of a second between exchanges. This gap is so short that it is comparable to the response time to a starting pistol, and it is only possible because we anticipate what people are going to say based on just their first few words.

Indeed, our use of language has evolved to become so efficient that we can decode the word "cat", for example, and link it to the animal involved more quickly than we can identify the sound of a cat meowing.

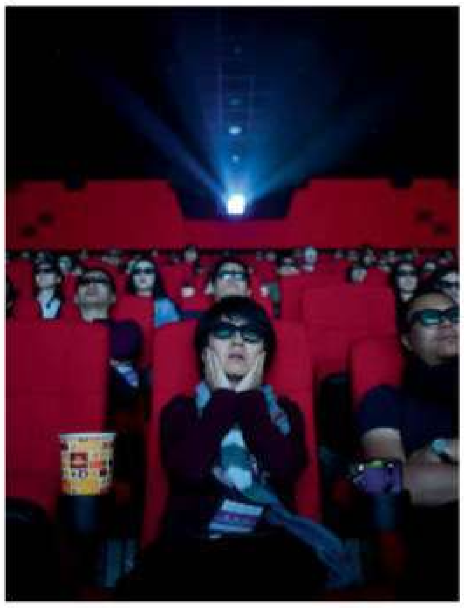
In *Talking Heads: The new science of how conversation shapes our world*, Shane O'Mara argues conversation isn't just important to us as individuals, it is at the very heart of our societies. He is well placed to tease this apart, as professor of experimental brain research at Trinity College Dublin in Ireland, having spent years exploring different areas in neuroscience.

O'Mara explains that the institutions around which we are organised, whether they are parliaments, churches or sporting organisations, are all maintained with some combination of meetings, boards or assemblies, and all of these are centred on conversation.

GARY BURCHELL/DIGITAL VISION/GETTY IMAGES

Conversation isn't just vital to individuals, but to societies as well

Of course, the back and forth that is essential to conversation would be useless without memory. O'Mara recounts the tale of Henry Molaison, who, in 1953, went through an experimental procedure to treat epilepsy in which the hippocampal formation in his brain was excised. His epilepsy did improve, but he unfortunately lost the ability to form new memories. This was so incapacitating that he had to live in a protected community.



WANG ZHAO/AFP VIA GETTY IMAGES

Different moviegoers show the same brain response to the plot

It is an often-told tale and a much-studied case, but here O'Mara goes beyond Molaison's own story and asks us to imagine a world in which we all lacked the ability to form new memories. None of our institutions could be maintained in such a scenario, and no amount of conversation could help. The seamless interweaving of language and memory is central to our societies.

Another vital connection here is how we share stories. Janice Chen, a researcher at Johns Hopkins University in Baltimore, Maryland, has run experiments where people's brains were imaged as they watched movies. She found that different people responded in the same way as a story unfolded.

Related work by Asieh Zadbood at Columbia University, New York, asked participants to recount the story of the film they had just watched to another person. She found that the responses of the listeners were very similar to those of the people relating the stories when they had originally watched the movie.

This is how storytelling allows collective memories to be formed and to act as a powerful binding agent within society.

> **"We spend 24 per cent of our time thinking about the future, compared with 5 per cent recalling the past"**

But there is another key twist here. As important as memory is, other studies have shown that we spend 24 per cent of our time thinking about the future, compared with just 5 per cent recalling the past.

O'Mara suggests that gifted political leaders use our collective memories of the past to offer an enticing vision of the future and that, in this way, modern nation states have been formed and continue to evolve.

Of course, this collective remembering is a process that will always be selective, and not always healthy. O'Mara points out that we are better at recalling past wars than past plagues and wonders how we will remember the covid-19 pandemic, and how that might affect the quality of our preparedness for the future.

Much of the history and sociology discussed in this book won't be new to readers, but O'Mara interweaves anecdotes with research findings in a way that manages to link it all to neuroscience. This is an intriguing approach, and makes for an enjoyable read. ▮

Tom Tierney is a writer based in Dublin, Ireland

Into the deep

There is still much to discover in the ocean's depths, as **George Bass** discovers in a gripping book

Book

The Underworld

Susan Casey

Doubleday

DESPITE the recent tragic loss of OceanGate's Titan submersible, people will continue to explore the ocean's darkest corners. Susan Casey, a smart documenter of the aquatic world in her previous books *The Devil's Teeth* and *The Wave*, helps us see why in her latest book.

The Underworld: Journeys to the depths of the ocean seeks to answer a question first posed by Aristotle as he dissected cuttlefish in the 4th century BC: what is beneath the ocean's surface?

The deep, it transpires, is so murky its boundaries can't be agreed by scientists. As Casey shares her definitions for the limits of the twilight, midnight and abyssal zones, she describes how life gets stranger the deeper you go.

There are carpets of "pale gold ooze" (likely to be clouds of micro-organisms) on the sea floor 600 metres down, alongside bronze cannons from the sunken Spanish galleon San Jose off the coast of Colombia. In the hadal zone – ocean trenches that extend from 6000 to 11,000 metres deep, named after Hades, the Greek god of the underworld – are dumbo octopuses (*Grimpoteuthis*), amphipods exuding their own armour and animals with photophores glowing like the "nuclear-blue lights of an airport runway".

The mid-Atlantic ridge contains hydrothermal vents, like this "black smoker"

B. MURTON/SOUTHAMPTON OCEANOGRAPHY CENTRE/SPL

This catalogue is interspersed with what attracted Casey to these habitats, including holidays by Canada's Lake Huron, where she fed hot dogs to sturgeon. She recounts the journey that took this childhood admirer of Jacques Cousteau – the naval officer turned TV aquanaut – to scuba diving, then to free-falling in a submersible for two and a half hours in the Pacific Ocean's abyssal realm, where the pressure is the equivalent of having "292 fully-fuelled 747s stacked on top of you". To finance this descent, she reached out to billionaires.

Exploration of the deepest regions is usually driven by a mineral gold rush or a disaster: the disappearance of flight MH370 in 2014 over the Indian Ocean, for instance, prompted a 1046-day scouring of this region of the abyss, the most thorough so far, she says.

What will future exploration find? Casey lists precious metals such as dysprosium and yttrium – used in smartphones. Then there are truly terrifying elements in sites like the bottom of the Tonga Trench, where the radioactive plutonium jettisoned in 1970 during the return of Apollo 13 is waiting.

Casey is critical of too much commercial activity on the seabed, especially as much of it is still unmapped. Already, sections are covered with litter and debris. She interviews Don Walsh, who visited the shipwrecks of the Bismark and the Titanic on a seabed so peppered with rusting debris she says it resembled "an explosion in a boiler factory".

There are also hidden dangers in the deep. We go to the Cascadia subduction zone off the western coast of North America, where a catastrophic megathrust event occurred in 1700. This created a magnitude-9 earthquake and tsunami that devastated Japan and British Columbia. It is, she reminds us, an event that typically occurs every 300 to 500 years.

The ocean depths also hold the key to reconstructing ancient climates to better understand our own era, as well as how life might look elsewhere. Casey quotes microbiologists who have seen white spires along the vent fields of the mid-Atlantic ridge: "This is an example of a type of ecosystem that could be active on [the moons] Enceladus or Europa right this second". How fascinating that Casey's underworld may shed light on future off-worlds. ▮

George Bass is a writer based in Kent, UK

New Scientist recommends

Corryn Wetzel

Reporter

New York

Given the summer heat in New York, board games have been the perfect way to hang out with friends or family while escaping the sun.

I can't stop playing **Wingspan**, a multiplayer game with an avian theme. Even if you're not a birdwatcher, you'll like this game. From whimsically coloured boards to the charming birdhouse that dispenses pastel bird eggs, it is a pleasure to play. The object is to recruit birds to your aviary, and beautifully illustrated cards guide your choice with scientific details about a species.

If you prefer a crowd-pleaser with almost no instructions, you could try **Wavelength** (pictured). Two teams take turns rotating a dial to find a target hidden on a colour spectrum, based on prompts. So, in response to the prompt card "tastes good vs tastes bad", one team member may say "blue cheese", leading to a heated debate on where the dial should land between the two.

This, it turns out, is just the right kind of heat.

DAVID STJERNHOLM

The TV column

Watch this space *Foundation*, drawn from Isaac Asimov's novels, is set in a world where an empire ruled by clones is under threat. Can the new season avoid fizzling out like *Game of Thrones*, asks an anxious **Bethan Ackerley**

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. She is still upset about the ending of *Game of Thrones*. Follow her on Twitter @inkerley

TV

Foundation

David S. Goyer and Josh Friedman

Apple TV+

Bethan also recommends...

TV

Game of Thrones

David Benioff and D. B. Weiss

HBO

Even if you haven't seen the show, you probably saw the outrage about its final season. Watch anyway: the dazzling heights of the first four seasons far outweigh its messy conclusion.

House of the Dragon

George R. R. Martin and Ryan Condal

HBO

This prequel to Game of Thrones *feels closer to a Shakespearean tragedy, as the Targaryen clan's destructive dramas play out.*

PATRICK REDMOND/APPLE TV+

In the second season, priests are spreading the Foundation's teachings

SOME TV shows leave you with trust issues. A friend recently told me she found the finale of *Game of Thrones* so awful that she no longer watches television.

I share her disappointment, and her words were on my mind as I watched the second season of *Foundation*, a glitzy space opera loosely adapted for Apple TV+ from Isaac Asimov's novels. It offers something I have craved since *Game of Thrones* went off the boil: an ambitious, character-driven drama concerned with how the writing of history shapes the present and the future. Could it live up to what it promised?

Foundation is set in the Galactic Empire, which is ruled by a genetically related dynasty. Dawn, Day and Dusk (Cassian Bilton, Lee Pace and Terrence Mann, respectively) are clones of the original Emperor Cleon, each decanted at a different age to reign as an orderly continuum.

But through his theory of psychohistory – forecasting the behaviour of very large groups – Hari Seldon (Jared Harris) has predicted the empire's fall. In the show's first season, he and his followers set up the Foundation, a community designed to preserve knowledge and react to potentially civilisation-ending crises.

Series two picks up with mathematics prodigy Gaal Dornick (Lou Llobell) and her daughter Salvor Hardin (Leah Harvey), who have awoken after over 100 years of cryosleep. The galaxy is now a very different place: the outer planets have been abandoned by the empire and the Foundation has flourished in its place. But a century ago, when Gaal refused to set up a second Foundation, the original Foundation diverged from Hari's initial plan and was set on a path to destruction. Gaal and Salvor must make things right.

> **"While it uses several ideas from Asimov's cerebral novels, at its heart, *Foundation* is closer to epic fantasy"**

This may not sound like an obvious companion piece to *Game of Thrones*, but bear with me. While it uses several ideas from Asimov's cerebral novels, at its heart, *Foundation* is closer to epic fantasy, full of courtly intrigue and swashbuckling adventures. It mines themes of power lying heavy with those who wield it, of sex and marriage changing history and of the lowliest citizens rising to heroic status.

The show is full of characters and adds more in its second season, such as Foundation acolyte Brother Constant (Isabella Laughland) and imprisoned general Bel Riose (Ben Daniels). For much of the series, most pursue their quests in relative isolation, spread across the galaxy and time itself. But, like *Game of Thrones*, *Foundation* weaves threads together towards a seemingly inevitable conclusion: the collapse of the old order and the beginning of a new one.

In today's TV landscape, it can be hard to trust that the creatives behind your favourite series know where they are going – particularly if you have been burned by a show's premature cancellation or disappointing finale. It is even changing the way many people watch TV, with some refusing to start a show until it has ended, ideally on its own terms and with consistently decent reviews.

If this sounds like you, I don't blame you for protecting yourself from a *Game of Thrones*-style letdown. But the show that *Foundation* has evolved into has renewed my faith that long-form TV can continue to compel. Like Gaal and Salvor, I have decided to trust in a higher plan – but the only thing I am risking is getting my TV-loving heart broken again. ▮

Events

NewScientist

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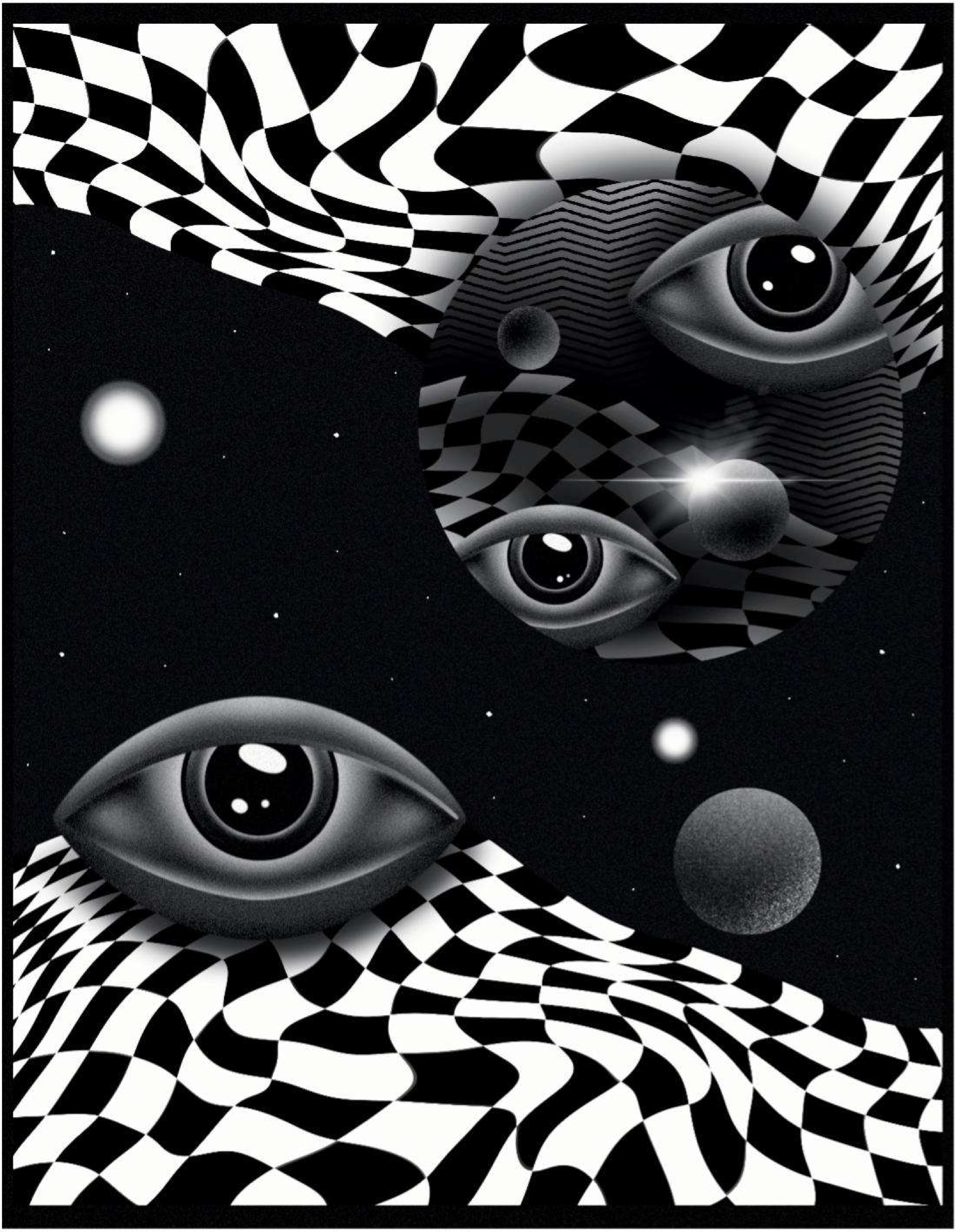


SLEEPLESSEYES

If space-time never forgets

The hunt for subtle signs of gravitational memory could unveil a cosmos saturated by symmetry and a new theory of gravity, finds **Abigail Beall**

WHEN black holes collide in the distant reaches of the universe, they release energy in the form of gravitational waves. You can picture these passing through space-time like the ripples a dropped pebble creates on the surface of a pond.

"In a pond, after the ripples pass, the water returns to its old level," says David Garfinkle, a cosmologist at Oakland University in Michigan. You might imagine that after the gravitational wave has passed, the fabric of the universe returns to normal too. "But it doesn't," says Garfinkle. In fact, Albert Einstein's general theory of relativity, which says that gravity results from mass warping space-time, predicts that gravitational waves should ever-so-subtly shift the structure of space-time in their wake. In other words, the universe remembers.

This "gravitational memory" effect is so weak that it might as well be homeopathic. But, in recent years, a few optimistic astrophysicists have taken up the challenge of trying to demonstrate its existence. "They hedge their bets about when," says Andrew Strominger, a theoretical physicist at Harvard University, "but nobody's saying we can't measure it." And now, as more gravitational waves roll in, we might be on the cusp of a breakthrough.

The implications of such a discovery would be far-reaching. Gravitational memory would be evidence of a hidden form of symmetry that is thought to saturate the whole universe. This, in turn, would provide vital and potentially decisive clues about a quantum theory of gravity – and what space-time is ultimately made of.

The roots of this idea stretch back to the late 1960s, when physicist Joseph Weber thought he had made a startling discovery. Using little more than vibrating aluminium bars, he picked up a signal that he claimed was the first detection of gravitational waves. Weber's announcement created a media sensation, but his peers were more cautious. Few physicists doubted the existence of gravitational waves, which fall directly out of the equations of general relativity, but the signal was expected to be so weak that it seemed unlikely Weber had seen it with his modest equipment.

Among the critics were two physicists called Alexander Polnarev and Yakov Zeldovich. To try to prove Weber wrong, they calculated how the biggest gravitational waves possible would affect Weber's vibrating bars. They imagined a super-dense cluster of stars in the centre of our Milky Way – far bigger than any cluster that actually exists there – making waves that disturbed two particles separated by 1000 kilometres. This was the same as the distance between Weber's bars, which he had placed in labs across the globe. Even in such an extreme case, they calculated, Weber's equipment needed to be 100 million times more sensitive to spot gravitational waves. "The detection was impossible," says Polnarev.

In proving Weber wrong, however, the pair happened upon a curious effect. The calculations revealed that particles vibrated by gravitational waves don't return to their original locations. Instead, their positions are shifted by a minuscule amount. This happens because space-time, which combines the three dimensions of space with one of time into a four-dimensional fabric, is permanently stretched in one direction and squeezed in another by the gravitational wave.

Polnarev knew that this idea of a permanent mark in space-time left by a passing gravitational wave might turn out to be useful. But back then, the idea that we might detect such waves was a moonshot, let alone this far weaker distortion of space-time. Over the next few decades, most physicists didn't give gravitational memory a second thought. Even in 2016, when the international collaboration behind the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the US announced the discovery of gravitational waves, the idea that we might someday see gravitational memory seemed a stretch to most.

Not to Paul Lasky, though. In the months before LIGO's announcement, he was among a select group invited to the Hilton hotel in Pasadena, California, to discuss the detection's implications. "We were all super excited," says Lasky, an astrophysicist at Monash University in Melbourne, Australia. Dozens of researchers darted between seminar rooms, discussing everything from how black holes merge to the nuances of LIGO's beam splitters. But gravitational memory? "I don't think it was on many people's minds, to be honest," he says.

Even so, Lasky found a small band of gravitational memory devotees. Alongside his colleagues from Monash, Eric Thrane and Yuri Levin, Lasky got chatting with Jonathan Blackman and Yanbei Chen from the California Institute of Technology. Unknown to each other, both groups had been working on a way to detect gravitational memory. The smoking gun would be a tiny, underlying shift in the ›

The irresistible attraction of gravity
Luciano Rezzolla lifts the lid on gravity and black holes at New Scientist Live newscientist.com/nslmag

ripples of the gravitational wave signal. That would be too weak for detectors like LIGO to see in individual events. But, by combining multiple events, they argued that they should be able to pick it out.

It wasn't straightforward. And Chen immediately spotted something Lasky had missed that would make detection even more difficult. But the researchers kept pushing. "It was a rollercoaster ride," says Lasky. "We were doing calculations in the middle of talks. Instead of going out for dinner, we were sitting in our rooms trying to solve this problem."

A week later, at the end of the meeting, they had nailed it. Contrary to the prevailing wisdom, their calculations showed that it was possible to find gravitational memory by combining data from LIGO and the Virgo detector in Italy. Exactly how many signals they would need to pull together was hard to predict – it could be as few as 500 or as many as 4000 – but the hope was that with about 1000 they would be able to magnify this minuscule effect enough to see it.

Now, with LIGO, Virgo and the Kamioka Gravitational Wave Detector in Japan having switched on again after upgrades, the milestone is within reach. New observations are rolling in every week, pushing the current total to over 100 and counting. At this rate, experimentalists hope they will detect gravitational memory within a few years.

That would be yet another confirmation of the predictions of Einstein's theory of gravity. Paradoxically, however, it could also help to demonstrate that it has its limits: gravitational memory could show how the black holes predicted by general relativity aren't the black holes we see.

Such a discrepancy could reveal itself in the very final moments of a merger between two black holes, as they orbit each other in a spiral before finally becoming one. The resulting black hole starts "ringing" – another way of saying it is wobbling about because of the collision – before it settles down to being a normal, well-behaved black hole, emitting some more gravitational waves in the process. From those gravitational waves, we can detect the shape of a black hole's "ringdown". And this will be slightly different depending on whether black holes obey the laws of general relativity or an alternative theory of gravity, says Lasky.

In general relativity, black holes are described by two numbers: their mass and their spin. Anything beyond these two parameters is known as "hair", so any black holes that didn't obey general relativity would be hairy, says Lasky. That means hairy black holes would ring differently from bald black holes. Which is why Lasky is trying to make "really precise measurements" of the black holes we can investigate via gravitational waves to see if there is any hidden hair lurking. If you want to really test general relativity, you can test this "no-hair theorem", says Lasky.

Hairy black holes

The problem, and the reason why gravitational memory could be useful, is that some of the signal it would produce is predicted to appear at the same time as the ringdown. To truly understand these ringdown gravitational waves, then, we must first know what contribution gravitational memory is making.

If researchers can tease the two signals apart and find that black holes are hairy after all, it would be the clearest sign so far that general relativity must be replaced by a theory of quantum gravity. This would unify gravity with the other forces of nature, which are described by quantum mechanics. What this quantum gravity might look like is far from clear, and experiments are yet to yield many clues. But gravitational memory offers hope on this front too, thanks to a strange quirk of nature that Strominger uncovered a few years ago.

This starts with the idea that instead of having a structure like a rigid crystal, with its three symmetries, empty space-time has an infinite collection of symmetries linked to gravity. These persist far from gravitational influence, however, as if there is a residual effect of gravity even when there is no matter around. These supertranslation symmetries, as they are known, can be described using the same mathematics used to describe gravitational memory – in other words, they are one and the same. So, an observation of gravitational memory would be a "spectacular confirmation" that supertranslational symmetries exist, says Andrea Puhm at the Centre for Theoretical Physics in France.

What Strominger realised, and what makes this connection particularly intriguing when it comes to quantum gravity, is that gravitational memory and supertranslational symmetries can be connected to a third, seemingly disparate part of reality: quantum particles with zero energy, known as soft

Electromagnetic echo

In the early 2010s, David Garfinkle at Oakland University in Michigan had been interested in gravitational memory, the permanent imprint gravitational waves leave behind on space-time (see main story), for a while. A mutual friend then introduced him to Lydia Bieri, who worked just down the road at the University of Michigan. Together, they realised that the equations they had been working on looked similar to James Clerk Maxwell's equations of electromagnetism. It got Garfinkle wondering: is there an electromagnetic equivalent of gravitational memory?

It turns out there is. Garfinkle and Bieri found that, just as gravitational waves leave behind a mark on space-time, electromagnetic waves are expected to leave their mark behind on charged particles by giving their velocity a kick. "It's very much like gravitational memory," says Garfinkle. This electromagnetic memory effect hasn't been shown experimentally, but Garfinkle and Bieri have a proposal for how that might be done, by sending short pulses through long antennas.

Electromagnetic memory isn't the only analogue to gravitational memory, either. There is an equivalent in quantum chromodynamics, too, which is the theory of the strong nuclear force that governs the quarks that comprise protons and neutrons. In this case, when a pulse of radiation passes a quark-antiquark pair, it should leave a mark on a property of quarks known as their colour charge. There have been hints of this colour memory at the Large Hadron Collider, but we need to wait for bigger machines like the Electron-Ion Collider to turn on to hopefully see it clearly.

SAKKMESTERKE/ALAMY

Gravitational waves are thought to permanently distort space-time

> "It was a rollercoaster ride. We were doing calculations in the middle of talks"

particles. Strominger showed that the way soft particles collide could be described by the same equations that govern colliding black holes that produce gravitational memory. Both sets of equations had been known about for decades, but nobody had made the connection.

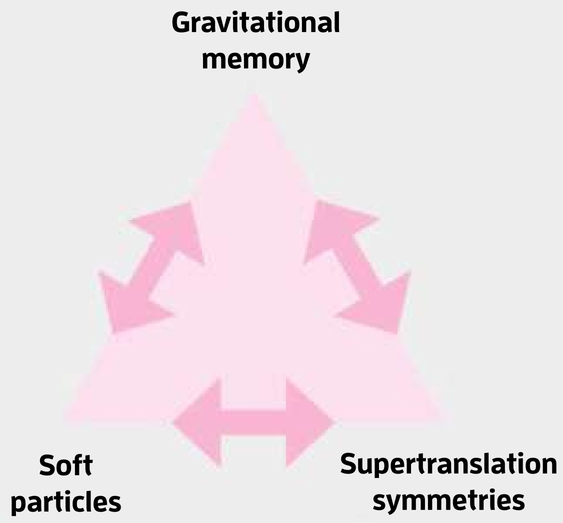
Strominger had found the third corner of what is known as the infrared triangle (see box, right): a mathematical connection that essentially says the soft particles theorems are equivalent to the supertranslation symmetries and to gravitational memory. That is a big deal because each corner of the triangle brings something to the table that helps us understand something about the others. The symmetries are intuitive, says Strominger, while the soft particle theorems are mathematically precise. "With gravitational memory," he says, "you connect it to observable reality."

There are also electromagnetic and quark versions of gravitational memory (see "Electromagnetic echo", left), each with their own triangles. Across the board, the memory effect is equivalent to special symmetries and to the interactions of soft particles. But these equivalent effects don't garner as much excitement, because the gravitational version of the triangle tells us what properties a viable theory of quantum gravity should have.

In short, this triangle suggest that any quantum theory of gravity must obey supertranslation symmetries. It is hard to find a theory that does this, which should help theorists to narrow their search. "It doesn't tell us what quantum gravity is, but it's going to help," says Lasky.

The infrared triangle

This mathematical connection links three seemingly disparate aspects of reality. Gravitational memory, which sits on one corner, is the physical manifestation of the other two corners. These corners, in turn, describe quantum particles and a special set of symmetries linked to gravity that show up even in empty space-time. This connection between the bottom corners of the triangle means that quantum gravity, whatever it is, must obey supertranslation symmetries.



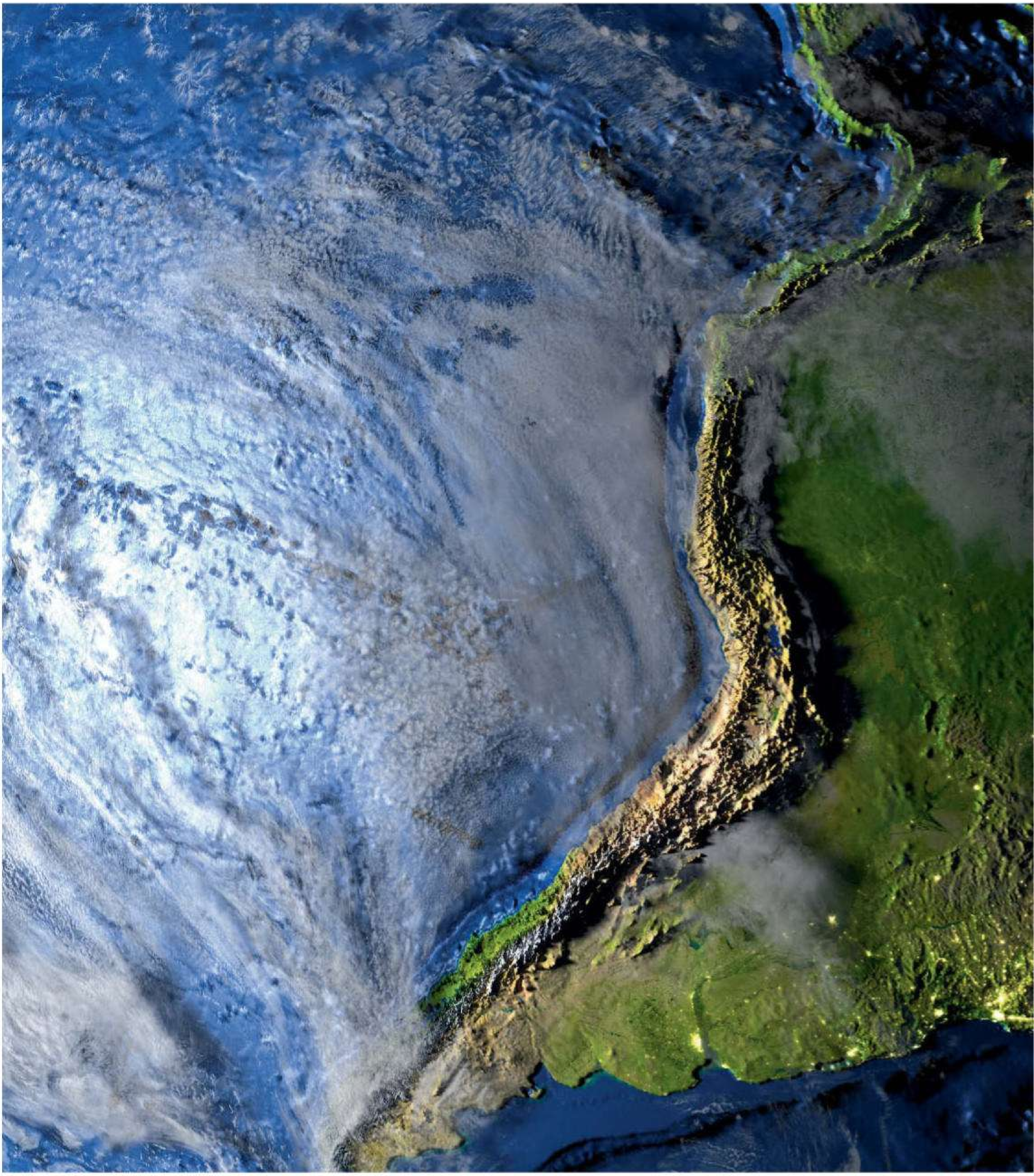
The infrared triangle could even help to prove that our universe is a hologram. A 25-year-old conjecture argues that the 4D space-time we experience is projected from a 2D surface governed by quantum theory, with no gravity, in much the same way a hologram projects from a surface. The idea that the universe is a hologram has been a favourite of physicists since it was first proposed, but the problem is that it only works for a strange kind of saddle-shaped space-time that doesn't resemble our universe. Finding a 2D quantum theory that maps onto our universe's space-time has proven tricky.

In June, Puhm presented calculations showing that if our universe's space-time abides by supertranslation symmetries then the corresponding 2D quantum theory must too. "Experimental confirmation of these symmetries would be a very important result," said Puhm at a recent gravitational memory conference at Queen Mary University of London. "But it would just be the start."

As if all that weren't enough, the infrared triangle has led to another surprising effect. When black holes obey supertranslation symmetries, they emit soft particles that end up on the surface of the black hole. The physical process in which this happens is thought to involve some kind of shock wave that subtly warps the black hole's event horizon – the point of no return for objects falling into a black hole. This is similar to the deformation of space-time caused by gravitational waves. "We refer to this as a 'black hole memory' effect," says Puhm.

First, though, the focus is on understanding gravitational memory and what it means for quantum gravity. For Polnarev, detecting gravitational memory will be a fitting end to 50 years of research into it, although he isn't yet sure how he will react. This doesn't worry him. "I am sure that if LIGO and Virgo manage to detect [the] gravitational memory effect," he says, "I will manage to solve the problem of the best way to celebrate." ▮

Abigail Beall is a features editor at *New Scientist*



HARVEPINO/SHUTTERSTOCK

A mystery in the Pacific

Why is a vast part of the ocean off Ecuador cooling instead of warming? It is a puzzle with big implications for climate change, finds **Madeleine Cuff**

FOR years, climate models have predicted that as greenhouse gas emissions rise, ocean waters will warm. For the most part, they have been correct. Yet in a patch of the Pacific Ocean, the opposite is happening. Stretching west from the coast of Ecuador for thousands of kilometres lies a tentacle of water that has been cooling for the past 30 years. Why is this swathe of the eastern Pacific defying our predictions? Welcome to the mystery of the cold tongue.

This isn't just an academic puzzle. Pedro DiNezio at the University of Colorado Boulder calls it "the most important unanswered question in climate science". The trouble is that not knowing why this cooling is happening means we also don't know when it will stop, or whether it will suddenly flip over into warming. This has global implications. The future of the cold tongue could determine whether California is gripped by permanent drought or Australia by ever-deadlier wildfires. It influences the intensity of monsoon season in India and the chances of famine in the Horn of Africa. It could even alter the extent of climate change globally by tweaking how sensitive Earth's atmosphere is to rising greenhouse gas emissions.

Given all this, it isn't surprising that climate scientists are trying to find out what is going on with increasing urgency. Like any good mystery, this is a tale of intrigue, confusion and competing theories. We haven't quite solved it yet. But just acknowledging its existence will help us plan for possible shifts. And by cracking the case, we will unlock the final details of our climate future.

The Pacific Ocean is the perfect place to harbour secrets. It is the largest, deepest ocean on Earth – so vast that it covers more surface area than all land combined. Getting a handle on how it will respond to increasing levels of greenhouse gases in the atmosphere is a mammoth challenge. That is in large part because there are big natural variations in the climate of the tropical Pacific, which influence weather around the world.

For example, every three to five years or so, the Pacific flips from La Niña conditions, where surface water temperatures in its equatorial region are relatively cool, to El Niño conditions, where these waters become warmer than average. This cycle, known as the El Niño-Southern Oscillation, or ENSO, is caused by changes in winds blowing across the ocean and movement of water between the cooler depths and the warmer surface.

Then there is the Pacific Decadal Oscillation. Its exact cause is unclear, but its effects mirror those of ENSO, although usually over a timescale of between 20 and 30 years. These changes make it hard to tease out long-term trends. So when researchers first spotted the cold tongue in the 1990s, they put it down to the region's extreme – but natural – variability.

Richard Seager at Columbia University in New York was one of the first to challenge this view. In 1997, he co-authored a paper warning that the equatorial Pacific was cooling, a trend not seen in climate models. Since then, data on sea surface temperatures has confirmed Seager's suspicions. The eastern Pacific (near the Americas) has always been cooler on average than the western part of the ocean (near Asia) by 5°C or 6°C, but between 1980 and 2019, this temperature difference widened by about 0.5°C.

Today, growing numbers of scientists have come to share Seager's doubts that the cold tongue can be explained by natural variability. If climate models fail to reflect the cold

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The cold tongue's future will have an impact on monsoons in India

SANJAY KANOJIA/AFP VIA GETTY IMAGES

tongue, they could be seriously misleading. "We have something to be concerned about and we need to figure out what it is," says Isla Simpson at the US National Center for Atmospheric Research.

This really matters because there are huge implications for our climate's future. Warming waters in the western Pacific and cooling waters in the east lead to more low-lying cloud over vast stretches of the eastern Pacific. "More intense clouds mean more reflected sunlight," says David Battisti at the University of Washington in Seattle. This, in turn, means less warmth entering Earth's atmosphere and getting trapped as a result of greenhouse gases. In other words, a cooling eastern Pacific slows the rate of global warming.

If the current trend continues, the cold tongue could reduce the level of projected global warming by a whopping 30 per cent compared with the predictions we get from climate models. That is the difference between global average temperatures rising by a further 1.3°C by the end of the century, or by a further 1.9°C. Crucially, the same volume of greenhouse gas emissions enters the atmosphere in both scenarios. However, it also means the base state of the climate would be more similar to La Niña, increasing the risk of droughts in the Horn of Africa and the US Southwest (see "A permanent US megadrought?", page 39).

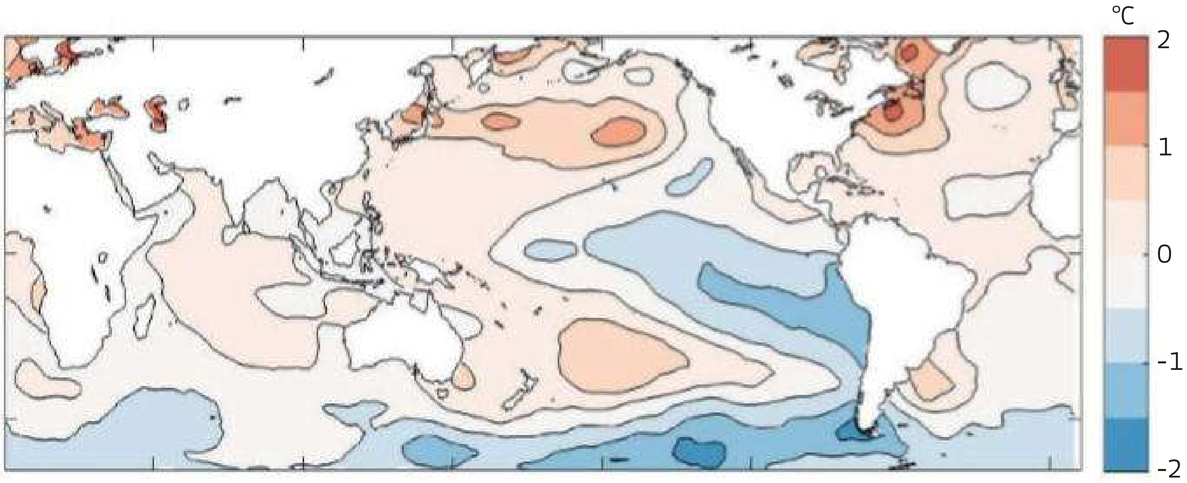
On the other hand, if climate models have got it right and the eastern Pacific warms, the rate of global heating will be higher and there will be different regional impacts. The base state of the climate will be more like El Niño, increasing coral reef bleaching, making the Amazon hotter and drier, bringing more droughts to Australia and Indonesia and leading to fatal heatwaves in India as monsoons fail. Meanwhile, parts of the Americas will experience more storms, with heavy rains leading to devastating floods and landslides in countries such as Peru and Ecuador.

Which future should we prepare for? If the cooling in the eastern Pacific persists, it will have "big implications for regional climate predictions", says Malte Stuecker at the University of Hawai'i at Mānoa. Yet at present, policy-makers, city planners and industry chiefs tend to get climate change forecasts based on models that feature a warming eastern Pacific.

To predict what will happen next, we first need to understand what is happening now. That is why some of the best brains in climate science are racing to discover why the real-world observations are so at odds with their climate models. There is no shortage of competing ideas.

Cooling, not warming

Between 1980 and 2022, sea surface temperatures increased by more than Earth's average temperature rise. But an area of the Pacific Ocean stretching from the east coast of South America has been cooling, defying climate model forecasts. This is known as the cold tongue.



Some think the answer could lie in the cold seas of the Southern Ocean around Antarctica. These waters, as in the eastern Pacific, are among the few places where sea surface temperatures have declined in recent decades. One likely driver is the melting of Antarctic glaciers as global temperatures rise. Another possibility is that ozone depletion and rising greenhouse gas emissions are strengthening winds in the region, intensifying the movement of cold air from Antarctica to the surface waters of the Southern Ocean. Whatever is causing the cooling there, Battisti and others theorise that it is having a knock-on effect in the tropical Pacific. Climate models don't always include Antarctic meltwater in their calculations and have trouble correctly reflecting changes to sea temperatures, winds and currents in the Southern Ocean. However, Yue Dong at Columbia University has shown that, when those errors are corrected, climate models do start to show cooling in the tropical Pacific. As a result, "the near-future warming projections by current global climate models may be overestimated", the work suggests.

Blowing cold

Another possible explanation for the cold tongue is that climate change is altering winds and ocean upwelling – the process of colder water from the deep ocean rising to the surface – in the Pacific. As already noted, the western Pacific is naturally warmer than the east. That is thanks, in part, to upwelling of cold water in the eastern Pacific, which keeps surface temperatures cooler there. As climate change advances, this is amplified, says Alexey Fedorov at Yale University. "When you increase carbon dioxide concentration, radiative effects [from sunshine] are more effective in the west because there is no moderating effect of cold water coming to the surface." As this warmer air over the western Pacific expands, it rises and heavier, cooler air rushes in to replace it, so that the prevailing winds (known as trade winds) blow more strongly from east to west. This amplifies the upwelling of cool water in the eastern Pacific, promoting further regional

A permanent US megadrought?

Since 2000, the US Southwest has been in the grip of a megadrought. The severe dry spell is dramatically changing the landscape, drying up lakes and threatening water supplies. This isn't what climate models predicted should be happening.

"Projections from our models don't suggest necessarily that precipitation should decline in the south-west," says Isla Simpson at the US National Center for Atmospheric Research. "At least in the wintertime, it increases over California, and there's neutral changes elsewhere." However, the megadrought is linked to another climate change anomaly called the cold tongue (see main story), a massive strip of water in the eastern Pacific that is cooling rather than warming as climate models predict it should.

If the cold tongue persists, drought looks set to become the norm in this part of the US, warns Simpson. Although unwelcome news, knowledge of this risk could be useful for state planners. For example, earlier this year, California, Arizona and Nevada agreed a strategy to cut water extraction from the Colorado river. However, it only holds until 2026, after which a long-term solution will be needed to manage drought in the region. "If we knew that this was going to be worse than we already think it is, that is useful information to have," says Simpson.

Melting Antarctic glaciers are cooling the Southern Ocean

SEBNEM COSKUN/ANADOLU AGENCY VIA GETTY IMAGES

cooling. But that effect is seldom factored in. "There are some persistent biases in climate models that prevent them from fully replicating this mechanism," says Fedorov.

It is most likely that a combination of these mechanisms is at play – with natural variation also a contributing factor. To crack the mystery, we need smarter climate models that are better at simulating everything from cloud cover to ocean currents, winds and melting glaciers.

DiNezio is pioneering this new generation of models using supercomputers. Early experiments have yielded promising results, they say, generating temperature trends in the Pacific that more closely match observed ones. But running the models is expensive and energy intensive, while access to supercomputers is limited because they are in such high demand.

Finding where the models are going wrong is only the first step in solving the cold tongue mystery, though. Ultimately, what everyone wants to know is whether the cooling trend is temporary or permanent.

Some, including Battisti, think the drivers of Pacific cooling – the melting Antarctic ice, for example – are here to stay, making this a trend that is likely to linger. That could help to mitigate the warming effect of excess greenhouse gas emissions over the coming decades. It would also reduce the destructive power of El Niño. "How strong El Niño events will be in the future depends a lot on how the long-term warming trends in the eastern Pacific turn out," says Stuecker.

However, some researchers think climate models will be proved right in the long run – that the basic physics of pumping vast volumes of greenhouse gases into the atmosphere means the eastern Pacific will eventually "flip" back to a warming state. When this reversal might happen is another matter: some say it could be in 20 years, others put it nearer to 100. "There are more mechanisms pointing to the El Niño-like warming in the very far future," says Sarah Kang at the Ulsan National Institute of Science and Technology in South Korea.

If it does flip back, we need to know how this will affect global warming as a whole. The current El Niño event, which is likely to peak later this year, offers an opportunity to explore this question. As the Pacific warms during this phase of ENSO, cloud cover above it will shift geographically – and climate scientists will be watching closely. "We can look at how the clouds respond to an El Niño event, and that might give us some idea of how the clouds will react under these long-term changes," says Stuecker, who is part of an international working group formed this year to study the cold tongue. This, in turn, will tell researchers more about the link between Pacific cloud cover and expected levels of atmospheric warming.

Any transition to a warming trend in the eastern Pacific would be globally disruptive, particularly if it takes us by surprise. Climate resilience plans, covering everything from water security to agriculture, could be rendered obsolete almost overnight, leaving nations scrambling to rebuild infrastructure and economies. "If we don't have the ability to predict when this is going to happen, then all of a sudden we are going to have these big changes in regional climate effects that we're not ready for," says Robert Wills at the Swiss Federal Institute of Technology in Zurich.

Despite all this, solving the mystery of the cold tongue isn't about proving climate models wrong, per se. On the big issues, from global average surface temperatures to Arctic ice melt, they have been remarkably accurate. When they warn that we are in for a warmer, wilder future, we can trust that they are correct. Rather, the cold tongue is the last big piece of the puzzle. Fit that in and we can build a more accurate picture of how life will change in a warming world – and how best to prepare for that future. ▮

Madeleine Cuff is an environment reporter at *New Scientist*

Fact or act?

The range of available health supplements is expanding at an astonishing rate. **Alison George** gets to the bottom of the claims behind this booming industry

AT MY local supermarket, I find myself seduced by the range of possibilities in the supplements aisle. Sure, I might be somewhat poorer if I succumb, but who wouldn't be tempted by a brain-boosting formulation including a range of nutrients that "help the maintenance of memory", or the promise of "super immunity"?

There is everything here that my body could need and more, from vitamin C and multivitamins to formulations with echinacea or turmeric. Online, things get more outlandish, with supplements promising everything from enhanced libido and sports performance to "thermogenic fat burning".

The sheer range of products on offer, and the claims that they are making, is overwhelming and confusing. On the one hand, we are blasted with messages about the nutritional inadequacies of the modern diet: surely adding concentrated doses of the good stuff extracted from food is helpful? Yet at the same time, large studies often suggest that many supplements have no discernible benefits.

"I'm concerned about this dizzying array of dietary supplements on the market, and that many people may be fooled into spending money on supplements that are not helpful to them and that could even be harmful," says JoAnn Manson at Harvard University.

So here is a guide to help you navigate the complex and often paradoxical world of nutritional supplements. We examine the evidence behind the promises on the labels so you can make better decisions about which products really deserve your hard-earned cash.

Scientific agencies such as the European Food Safety Authority (EFSA) define supplements as concentrated sources of nutrients or other substances with a "nutritional or physiological effect". These may provide vitamins, minerals, essential fatty acids, fibre, plant or herbal extracts and include live organisms such as probiotics. They come in a variety of forms: tablets, capsules, liquid doses or, increasingly commonly, gummies.

We are guzzling supplements like never before. In 2022, the market reached $164 billion, driven by factors such as an ageing population and the greater focus on personal well-being. "The biggest trend underlying all this is self-care," says Carrie Ruxton at the Health and Food Supplements Information Service, a UK-based industry body. The number of available products is also booming. In 1994, just 4000 different supplements were available in the US. Today, there are about 90,000, with around 1000 new products coming on the market each year.

> "A US study found that 12 per cent of sports supplements contain prohibited drugs"

Our hunger for supplements dates to the early 20th century, after the first vitamin to be identified, now called vitamin B1, was isolated in 1910. We now know that there are 13 essential vitamins, and around 20 essential minerals, such as zinc, calcium and iron, that must be obtained from food, as the body can't produce them in sufficient quantities.

Along with these discoveries came the notion that nutritional supplements were beneficial for everyone, and it wasn't long before such products hit the market. One of the earliest was Mastin's Yeast Vitamon Tablets, created in the US in 1916. Containing iron, calcium and vitamins A, B and C, advertising posters claimed it would "strengthen nerve force, enrich the blood, clear the skin and act as a general health-building tonic".

So began a long tradition of creating novel dietary supplement formulations based on a new understanding of nutrition and then marketing these products with sometimes extravagant statements about their benefits. In 1991, Japan became the first country to regulate food supplements, introducing a system to approve statements about the effects of food on the human body. Other countries soon followed suit with their own systems for ensuring the quality and safety of dietary supplements and – crucially – vetting the health claims found in the products' marketing.

The most straightforward are so-called structure/function claims, such as: "Vitamin D contributes to the maintenance of normal bones." According to EFSA – whose guidelines the UK currently applies – and the US Food and Drug Administration (FDA), these claims can be added to any product that contains a large enough dose of the specified substance.

Then there are authorised health claims that contain more specific details, such as: "Calcium and vitamin D help to reduce the loss of bone mineral in post-menopausal women. Low bone mineral density is a risk factor for osteoporotic bone fractures." To permit this kind of statement, most regulatory bodies would require convincing evidence from clinical trials linking a particular substance in the supplement to a reduced risk of disease. The trials needed to prove such a relationship are costly and complicated to conduct, and there is a long list of substances that failed to make the grade.

EFSA also requires extensive checks to ›

PHILIP HARRIS

ascertain the safety of any new supplement's ingredients. The FDA, by contrast, carries out no such checks. "In the US, we're at the mercy of manufacturers when it comes to the safety of their products," says Pieter Cohen at Harvard Medical School. "There's zero requirement that the product or the ingredient needs to be tested prior to being sold to consumers." Cohen's research has uncovered prescription medications such as sildenafil in supplements marketed for sexual enhancement and unapproved drugs in supplements marketed for cognitive enhancement sold in the US. And a whopping 12 per cent of sports supplements contain FDA-prohibited substances, he has found.

Manson is similarly concerned, describing the situation as a "Wild, Wild West". If you live in a country like the US without pre-market testing, she advises only selecting products from reputable retailers that have at least been accredited by a high-quality third-party certification programme.

TikTok tales

The situation can get far wilder online, where you can find many supplements with extravagant claims, especially with regard to weight loss, muscle building and sexual performance. What's more, unless they are from a reputable retailer, you will have no idea what is really in them: they could be sugar pills or contain pharmaceutical ingredients. Although these products should still conform to national regulations of the country in which they are manufactured and the countries in which they are being sold, the enforcement is much trickier for products available online, meaning dubious products can easily fall into consumers' hands. "You should be very cautious. You should buy products from reputable brands. If you're seeing claims for a product that seem too good to be true, they probably are," says Steve Mister, president of US trade organisation the Council for Responsible Nutrition.

Users of social media platforms such as TikTok can create fads for products with little-to-no proven benefits. Consider a plant extract called berberine. One user documented dramatic weight loss that she claimed was due to this supplement, resulting in it being dubbed "nature's Ozempic" – a reference to the prescription diabetes drug, which is also used for weight loss. A close look at the scientific literature, however, reveals scant evidence that berberine can help people shed pounds.

Lost in translation

In the world of food supplements, certain terms have become common. Mostly used by marketers, not nutrition scientists, none has an agreed definition.

Functional food: a food that has been formulated to contain some putative active ingredient with health benefits (even though a truly "functional" ingredient, with strong scientific evidence for its benefits, is rare).

Nootropics: over-the-counter dietary supplements marketed to improve memory and mental focus.

Nutraceutical: used to describe a food-derived product with purported health or medicinal benefits over and above its basic nutritional content

Superfood: a food that somebody is promoting for its believed benefits.

A healthy diet is by far the best source of essential vitamins and minerals

JUAN PABLO OLAYA CELIS/SHUTTERSTOCK

Even mainstream products from reputable retailers may lead consumers astray. Let's take a hypothetical "immunity boost" supplement. The label displays the word "echinacea" prominently, along with a picture of this plant. The problem is that, although echinacea has a reputation as a herbal medicine for improving the immune system, the evidence for its efficacy isn't yet sufficient to permit an authorised health claim, according to EFSA and the FDA. When you read the back of the box, however, you will find that the product includes vitamin C, for which the statement "contributes to the normal function of the immune system" is permitted. While that is factually true, it doesn't necessarily mean that this particular product will give your immune system a boost to protect you from your next cold or a bout of covid-19; it is simply stating vitamin C's role in the human body.

> "The labels say things like 'Endurance' or 'Clarity' and they don't need any science to back up those claims"

Often, the language on the labels is ambiguous enough to circumvent the regulations. "They say things on the packaging like 'Endurance' or 'Clarity'," says Cohen. "And it's like, 'Wow, that's really attractive. I want clarity, too.' And they don't need any science to back up those vague claims." For many botanical ingredients, there is scant evidence that they benefit our health in the way they are reputed to – and the evidence cited is often based on animal studies or human trials with just a few participants.

So what, if anything, actually does work? There is no doubt that supplements of vitamins and minerals have had incredible impacts on global health by resolving specific deficiencies, from scurvy (which arises from a lack of vitamin C) to neural tube defects (which can arise from a lack of folic acid). They can also be useful tools for tackling specific conditions. One recent success story is the supplement AREDS2, which contains strong doses of vitamins C and E, as well as copper, zinc and the plant pigments beta carotene, lutein and zeaxanthin. Studies suggest it can slow down vision loss in people with more advanced stages of age-related macular degeneration, even though it doesn't prevent the early stages of the disease.

The big question is whether supplements can give a boost to people without any particular illness or diagnosed deficiency. Some of the best-conducted studies have looked at multivitamin tablets containing a host of nutrients in one pill. The Physicians' Health Study, for instance, followed nearly

Sister Lauras Food
MODIFIES FRESH MILK FOR BABIES AND INVALIDS

FOX PHOTOS/GETTY IMAGES

The supplements industry emerged in the early 20th century

15,000 men for 11 years and, in 2012, it found that multivitamins resulted in a "small but significant 8 per cent reduction in total cancer", says Manson. Unfortunately, a later study examining an even larger sample failed to detect a similar effect.

Such research shows that the effects of simply upping our dosage of basic essential nutrients are far from clear-cut. Last year, the US Preventive Services Task Force – the independent body that makes evidence-based recommendations on disease prevention – conducted a meta-analysis of these trials and others, concluding that there was insufficient evidence to assess the balance of benefits and harms of multivitamins to prevent cancer or cardiovascular disease. It also advised against the use of beta carotene supplements, which appear to slightly increase the risk of lung cancer in people already susceptible. However, multivitamins may slow cognitive decline.

What do you really need?

Although many supplements (excluding vitamin D) aren't required for most people consuming a balanced diet, top-ups of the following nutrients are recommended for certain groups.

Folic acid: for pre-conception and for the first trimester of pregnancy.

Iron supplements: for people with iron-deficiency anaemia.

Long-chain polyunsaturated fatty acids: for those who don't consume oily fish weekly.

Vitamin B12: for vegans.

Many people who take supplements may already be getting the nutrients they need in their diet. If you eat lots of fruit and vegetables, fibre and fish each week, "the only thing that you might need is vitamin D", says Ruxton (this would depend on environmental sunlight levels and skin tone). If you really care about your health, you would do better to ensure you are eating such a diet before you decide to pop any pills. "Supplements can be complementary to a healthy diet, but they will never be a substitute for a healthy diet," says Manson.

Personalised nutrition

By averaging across huge swathes of the population, however, the large clinical trials may miss the benefits to smaller groups of individuals who may be at risk of a particular nutrient deficiency and could therefore benefit from a helping hand. "Children, pregnant women, vegans, the elderly have specific needs," says Bernadette Moore at the University of Leeds, UK (see "What do you really need?", left). In the future, we may have "personalised nutrition", using blood samples or genetic testing to more precisely identify who may benefit from a concentrated dose of particular substances. To take one example, variants of the *MTHFR* gene can change how people respond to different forms of vitamin B9 – the folic acid and folates that should be consumed during pregnancy. Assuming that you are already meeting your basic dietary requirements, however, simply blasting your body with a "megadose" of a particular nutrient may provide no benefits and could even cause considerable harm. Turmeric supplements, purported to have anti-inflammation effects but which show inconsistent results in clinical trials, have been linked to liver damage, for example, and vitamin A can be lethal at high doses. Taking too much vitamin D has even been shown to reduce bone strength, since the higher doses may hinder hormones that promote bone formation. "If you're megadosing on a single nutrient, it could interfere with the absorption or bioavailability of others. It is generally not good practice to megadose," says Manson.

Such concerns are unlikely to stem the tide of new products, as tentative scientific discoveries quickly inspire new marketable goods. Just consider the explosion of interest in the amino acid taurine, after animal studies published in June revealed that it improved the health and lifespan of mice and monkeys.

That's not to mention the constant attempts to improve even our most basic vitamins. "The supplement sector is one of the most innovative sectors that exist in the area of food," says Patrick Coppens at Food Supplements Europe, a European industry body. A new, faster-acting form of vitamin D is currently being evaluated by European regulatory authorities and is already available in Australia. Mushroom powders with high levels of vitamin D have recently gained EFSA approval, as has a new form of iron that mimics the natural form found in animals and plants, so is better absorbed by the body.

Such innovations may be impressive, but for now, you would do well to exercise a little critical thinking when tempted by a new product. You can ask your doctor if you are likely to have a particular deficiency and look online at some credible resources – such as fact sheets from the US National Institutes of Health Office of Dietary Supplements and assessments made by EFSA, for instance – to find out the latest evidence behind the claims.

In many cases, you may find it is better to save your money or invest it in more fruit, vegetables and fish. Your body and your bank balance may be healthier as a result. ▮

Alison George is a features editor at *New Scientist*

Puzzles
Try our crossword, quick quiz and logic puzzle p45

***Almost* the last word**
Why do almost all vertebrates have tails? p46

Tom Gauld for *New Scientist*
A cartoonist's take on the world p47

Feedback
Woolly science and going creak at the knees p48

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p48

60-second psychology

Yes and no

Taking on too many commitments can leave us exhausted and full of regret. **David Robson** offers a life hack that can help you say no

David Robson is an award-winning science writer and the author of *The Expectation Effect: How your mindset can transform your life*

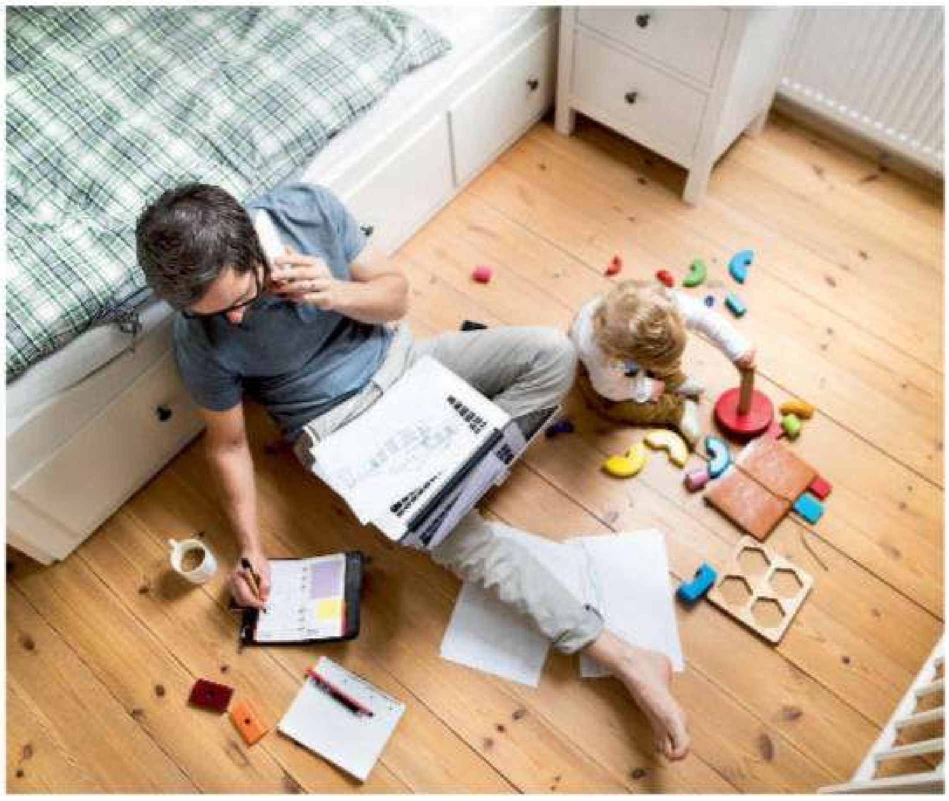
AS A conscientious tracker of my health data, I have recently noticed a striking improvement in some key metrics. I sleep more soundly and my heart rate variability – which reflects physiological stress levels – has never been better. My mood is also a lot brighter.

I am conscious that correlation isn't causation, but these changes have happily coincided with a new life hack I discovered a few weeks ago, which can help us all to manage our time more effectively.

It hinges on a psychological bias known as the "yes-damn" effect, which describes how we often agree to take on too many future commitments, only to regret the decision once the time comes to complete the tasks. It is the reason that our diaries are often packed full of obligations without any space for rest and relaxation as we rush to meet each goal.

Work by Gal Zauberman and John Lynch while they were at Duke University in North Carolina suggests that the yes-damn effect arises from a flaw in our memory and imagination. When we think about our schedule for the weeks or months ahead, we forget the mundane tasks in the background of our lives: errands, housework, doctor's appointments – things that won't just disappear when the time approaches.

This creates the impression of more slack in our schedule than we have, leading us to overcommit to new responsibilities. "We get tricked into thinking that the future will be some magical land of free time," writes Hal Hershfield in his new book, *Your Future Self*.



WESTEND61/GETTY IMAGES

It isn't that the tasks themselves are undesirable – recent research suggests that we are particularly likely to overestimate our availability when we contemplate an activity we know we will enjoy. I know I am guilty of this wishful thinking, and thanks to the yes-damn effect, I am typically left feeling so stressed with the time pressure that I fail to relish the opportunity that had once seemed so enticing.

What can be done? One simple rule of thumb for time management is to estimate how long each new activity will take, then double it. This will make your schedule look far busier than it really is and prevent you from overcommitting.

Alternatively, when you are contemplating a new task, you might try to imagine that you had to do this activity tomorrow. Would you still take it on, despite all the other pressing demands that you know you will have in the coming days? If so, the rewards will outweigh the costs and you should say yes. If the answer is no, you might reconsider.

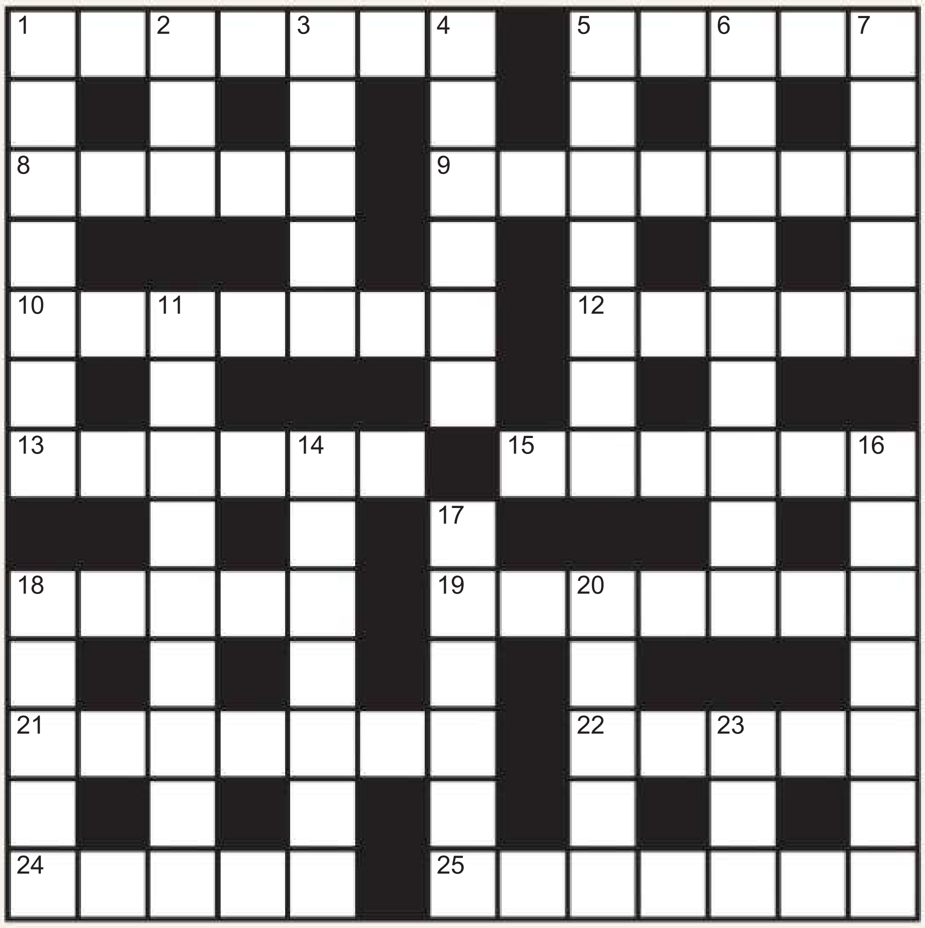
Putting this into practice, I have found that the initial decision to turn down what sounds like a really exciting opportunity can feel painful, but I am now thankful for the increased free time and reduced stress. Let's call it the "no-yay effect". ▮

60-second psychology appears monthly

Next week
Stargazing at home

These articles are posted each week at newscientist.com/maker

Cryptic crossword #115 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Electricity pioneer from distant time period penning article (7)

5 Sports stuff for sale in the auditorium (5)

8 Stick end of prong into vein (5)

9 Mushroom mania at dances (7)

10 Tomato ruined new piece of furniture (7)

12 Private meal starts late (5)

13 Apply waterproof surface to brown patterned cloth (6)

15 Mortified: silver has bit of tarnish (6)

18 Healing lotion left in stockpile (5)

19 Get a letter from Greek woman in a garden (7)

21 Redesigned AI drone using air pressure but no liquid (7)

22 Fired bricks, maintaining temperature (3,2)

24 Glue part of Sherpa's tent (5)

25 Electricity pioneer put 10-Watt energy in shopping centre (7)

DOWN

1 Short chap and university teacher initially quarrelled (4,3)

2 Staff of gold in Paris uprising (3)

3 Fantasise about being in major engineering project (5)

4 Has a desire a nurse fills? Yes (6)

5 Making fabrics, we average about nine, essentially (7)

6 Girl who grew and shrank drinking fluid near Daleks, maybe (5,4)

7 Radiant body involves one step (5)

11 Farmers sometimes grabbing hour for exciting reads (9)

14 Solvent expert scribbled note (7)

16 Foolishly fret over salad dressing ingredient for clover-like plant (7)

17 Arbitrary R&D mantra: eliminate repetition (6)

18 Deception by quiet rascal (5)

20 Sounds like the guy runs his tongue along coil (5)

23 Starts to type out every digit (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #213

set by Bethan Ackerley

1 Which of the following doesn't constitute a single species that is the only extant member of its genus: the shoebill, the vampire squid, the ginkgo or the gorilla?

2 The movement of an organism in response to chemical stimuli is known as what?

3 Who, in 2022, became the second woman ever to win the Fields medal?

4 In what year was a pulsar first detected?

5 What is the fatty substance that surrounds the axons of nerve cells?

Answers on page 47

Headscratcher

set by Howard Williams

#233 An odd league

The annual football tournament between the teams in the town of Oddhampton has just reached a thrilling climax.

The five teams played each other once, earning two points for a win and one for a draw, with the mathematically pleasing result that four of the teams finished with a different odd number of points.

The spectators were less pleased, however: the number of goals scored was the minimum necessary to produce this result.

What was the total number of goals scored in the tournament?

Solution next week

Telling tales

Why do almost all vertebrates have tails, even when they don't seem useful, but apes and frogs don't?

Stephen Johnson
Eugene, Oregon, US
All non-aquatic vertebrates descend from a common ancestor, a tetrapod of approximately 360 million years ago – which possessed a tail. The existence of the tail was primarily for balance, particularly when using only the rear legs, such as when feeding in trees. However, the tail evolved to have many uses, for example allowing primates extreme agility in the arboreal portions of forests.

It isn't true that apes and frogs don't have tails. Frogs have five different metamorphic life stages and possess a tail when they are tadpoles, tadpoles with legs and froglets. In fact, frogs couldn't survive without their tails (and gills) before they move to their final stage on land.

All primates have tails, including humans. Human tails aren't external, but consist of three to five fused vertebrae known as the coccyx, or tailbone.

> “We may not be able to wag our tails when happy, but we are very unhappy if anything happens to our tailbone”

Some might think the coccyx is vestigial and serves no purpose, but, in fact, it has several important uses. Many muscles attach to the coccyx, and it provides support for important structures, such as the anus and the vagina. It also provides support of the rest of the body when sitting.

We may not be able to wag our tails when happy, but we are very unhappy if anything happens to our tailbone.

Nicole Keshav
Cambridge, UK
Apes and frogs have vestigial tails in the embryonic stages. The tails don't develop because they aren't needed by the adults.

Will this change in the distant future? It is certainly possible!

Garry Trethewey
Arkaroola, South Australia
There are several approaches to answering this question.

Let's look at “even when they don't seem useful”. Evolutionary theory describes a great game of trade-offs. Overall, any feature that persists must have more benefits than costs.

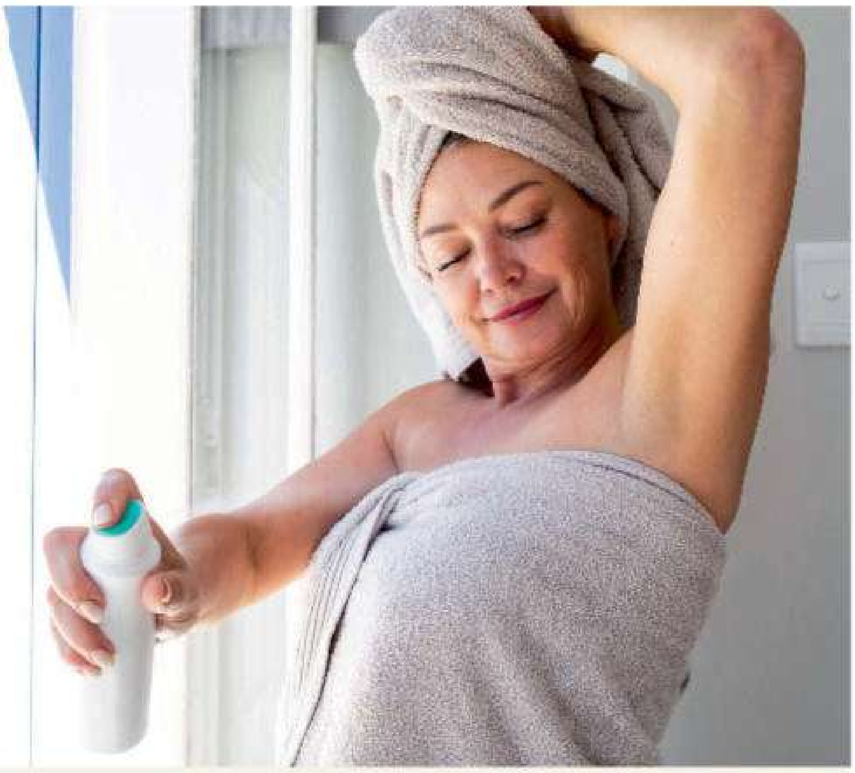
As an example, a bearded dragon incurs the cost of growing and maintaining an extra 10 per cent of its body (due to its tail) and the cost of having to run further into a crack in a rock to be safe from capture.

It appears to me that being tailless would be an advantage to a bearded dragon. But that only indicates my lack of knowledge.

Let's look at why apes and frogs don't have tails. They actually do possess much reduced tails. Humans develop a tail until about eight weeks of gestation, after which it stops developing and remains as a coccyx – our tailbone. This is a group of three to five vertebrae fused into one to five bones. This lack of definition suggests very minimal function.

Back to evolutionary theory. At some time, and in some environmental circumstances, apes and frogs with smaller tails did better than those with bigger tails.

Once the machinery for developing a functional tail had disappeared, it is unlikely that it would re-evolve from scratch.


WESTEND61 GMBH/ALAMY

Why do aerosol cans suddenly become very cold when they run out?

This week's new questions

Cold spray **Why is it that, when spraying an aerosol can of deodorant, it suddenly becomes very cold when it runs out?** ***Helena****, Colchester, Essex, UK*

On a roll **When a round coin rolls down a slope, it stays upright, so why does a “square” coin sliding down a slippery slope soon fall over?** ***Ed Stefaniuk****, Yarm, North Yorkshire, UK*

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Good boy

Why do humans pat animals on the head? I know we do it with cats and dogs, but I recently saw footage of a diver trying to pat an octopus.

Jan Horton
West Launceston, Tasmania, Australia
This year, I was bequeathed a scrap-metal duck sculpture that is kept beside my front door.

Since it arrived, I have noticed that nearly every visitor (including real estate reps, religious door knockers and delivery people, as well as friends) seems impelled to pat it on the head, though a subset are likely to stroke the bill instead.

I do wonder if it is, in part, the convenient height of the head for an interaction?

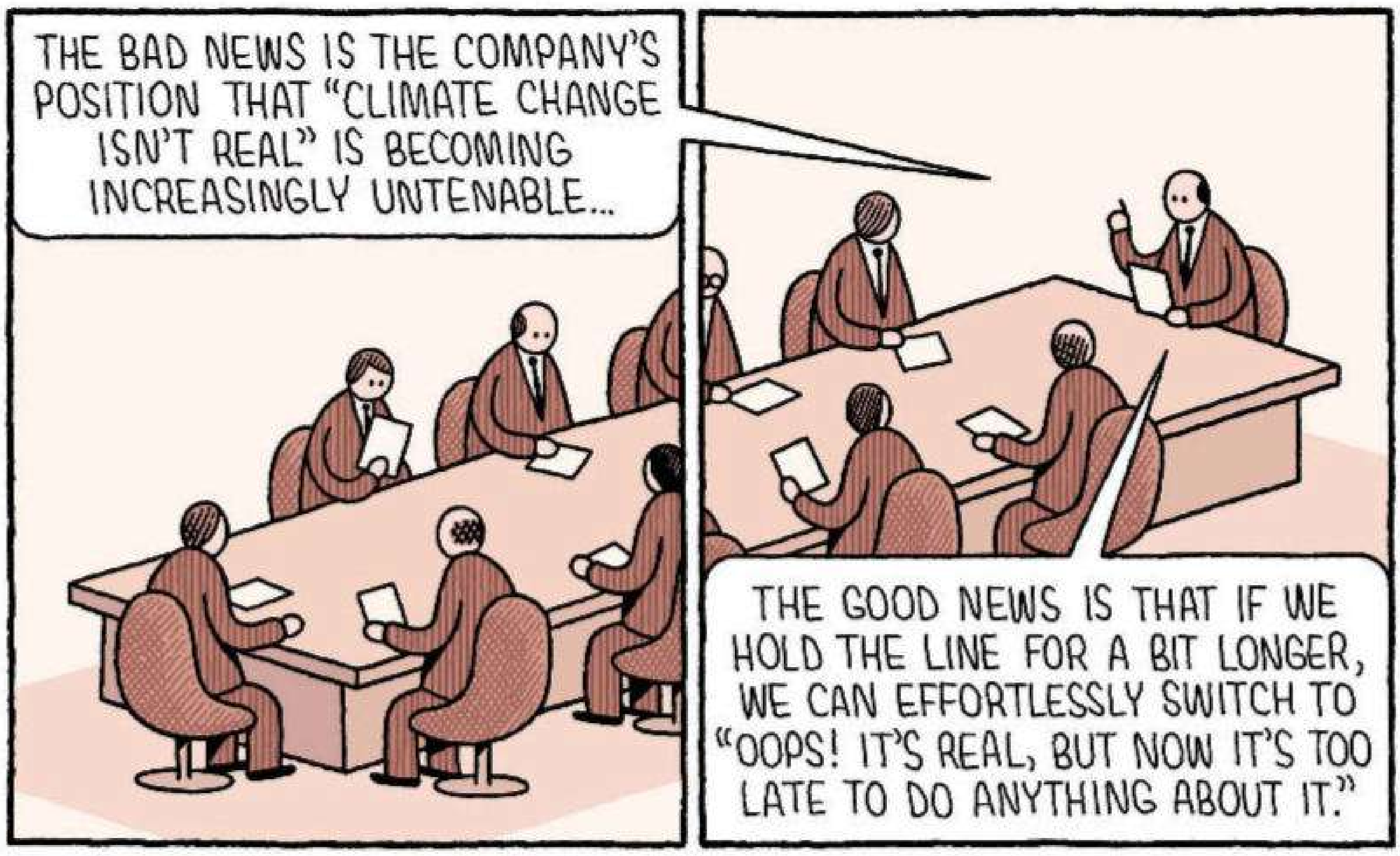
Accent origin

People from all over Europe settled in North America in the 17th century, so how and when did the North American accent develop? (continued)

Mat Macmillan
Tauranga, New Zealand
I have been following the previous answers to this question, and I notice that no one has made allowances for the effect of interactions between native English speakers and Native Americans, who learned to use English with their own unique intonations.

I came across this idea many years ago while reading *Zen and the Art of Motorcycle Maintenance*. As an English person living in New Zealand, I find it easy to see how this same process could have generated the Kiwi accent.

Tom Gauld
for New Scientist


THE BAD NEWS IS THE COMPANY'S POSITION THAT "CLIMATE CHANGE ISN'T REAL" IS BECOMING INCREASINGLY UNTENABLE...
THE GOOD NEWS IS THAT IF WE HOLD THE LINE FOR A BIT LONGER, WE CAN EFFORTLESSLY SWITCH TO "OOPS! IT'S REAL, BUT NOW IT'S TOO LATE TO DO ANYTHING ABOUT IT."

Claire Cassidy
Bethesda, West Virginia, US
In a previous answer (10 June), James Cawse mentioned valleys in West Virginia where some people continued speaking a form of Elizabethan English into the 1960s.

The whole issue of where American accents came from is interesting and much studied. As in the UK, there are many different accents and accent sources, depending on the immigrants who first settled a region.

For a thorough study of American dialects please see the Dictionary of American Regional English (DARE), a six-volume work that documents words, phrases and pronunciations that vary from one place to another across the US. You can find more details at dare.wisc.edu.

Stacking it up

Is there a correct way to fill a dishwasher to maximise capacity and cleanliness? (continued)

> **"Surely the correct way to load a dishwasher is into a van to take to the scrap metal dealer, and to use the sink thereafter?"**

Keith Macpherson
Clevedon, Somerset, UK
Raúl Pérez Mohedano (10 June) suggests opening the dishwasher immediately after it has finished. I caution against this without first checking the materials and construction of the surrounding countertops.

The hot, moist efflux from the dishwasher will, over time, degrade any fibreboard in the vicinity, resulting in a possible collapse of the worktop.

W. Richard Hencke
Scotts Valley, California, US
The problem with placing like with like in the cutlery basket, as previously suggested, is that they love to nestle on top of one another, impairing the cleaning process.

I take pains to do the opposite, so that all surfaces are exposed to the jets. An exercise in applied topography I suppose.

Hillary Shaw
Newport, Shropshire, UK
Given the energy, water and raw materials that go into its manufacture and transport, then its usage when most households consists of five people or less, then any repairs and, finally, its disposal, surely the correct way to load a dishwasher is onto the back of a van to take to the scrap metal dealer, and to use traditional kitchen sink washing up thereafter.

Mick Micklethwaite
Petersfield, Hampshire, UK
Your previous correspondent (8 July) is absolutely right that two dishwashers is the solution, and we have recently set up our new kitchen just so.

There is a problem, however. It means emptying two dishwashers instead of one, neither of which has been stacked correctly. ▮

Answers

Quick quiz #213
Answers

1 The gorilla – there are two gorilla species, *Gorilla gorilla* and *Gorilla beringei*
2 Chemotaxis
3 Maryna Viazovska
4 1967
5 Myelin

Quick crossword #138 *Answers*

ACROSS 1 Perrin, **4** Tubercle, **9** Resist, **10** Sapphire, **12** Ox Beetle, **13** Angina, **15** Iodotyrosine, **18** Arctic circle, **21** Unwrap, **22** Dialysis, **24** Kilogram, **25** Corona, **26** Great auk, **27** Enamel

DOWN 1 Periodic, **2** Rosebuds, **3** Inspector Gadget, **5** Upas, **6** Exponential horn, **7** Clinic, **8** Enemas, **11** Clarity, **14** Psychic, **16** Ice storm, **17** Sea snail, **19** Muskeg, **20** Twelve, **23** Baku

#232 Opposite number
Solution

Belle lives at number 49.

The total number of houses on the lane, N, must be an odd number (double the number on each side plus the one house at the end). The opposite pairs of houses are numbered 1 and N then 2 and N - 1 and so on. In other words they always add to N + 1, which is an even number. Stan's number is 45 per cent more than Leah's, which means Leah's has to be a multiple of 20. This makes for several possibilities for the pair's numbers: 20 and 29, 40 and 58, or 60 and 87. Since the two numbers need to add to an even number, Leah and Stan live at 40 and 58, and the house at the end is number 49.

Sheepish fears

Jessica Monk, Dana Campbell and Caroline Lee, at government research agency CSIRO in Armidale, Australia, gathered knowledge about how difficult it can be to predict whether some particular thing will (a) attract a sheep or (b) scare the sheep. Details are in the journal *Animal Production Science*.

They performed experiments exposing sheep to a dog sitting in a window, and to the window without the dog. They tried giving the sheep drugs to reduce anxiety and giving them drugs to increase anxiety.

They tried using food as a tempting distraction when the sheep encountered something scary. Would they choose to flee the menace or stay for the snack? Alas, calibrating the interplay of food, fear and sheep proved too complex for the researchers' current understanding of sheep cognition. Offering food as a sheep distractant, they say, should be attempted only "in future studies where appetite is not expected to be a confounding factor".

Monk, Campbell and Lee also point to a quasi-lively 1982 experiment by Judith Franklin and G. D. Hutson at the University of Melbourne, recorded in the journal *Applied Animal Ethology*. Franklin and Hutson, they say, "found that the use of a taxidermy sheep as an attractant was unsuccessful as test sheep showed fear responses to the taxidermy model rather than affiliative responses".

Urchin teeth inspiration

Politicians who screech the word "diversity" as an epithet to inflame their followers' all-purpose anger have yet to hoot specifically about tooth diversity. Actual information, should those politicians desire to seek any, about tooth diversity is in fresh supply in a study called "Tooth diversity underpins future biomimetic replications".

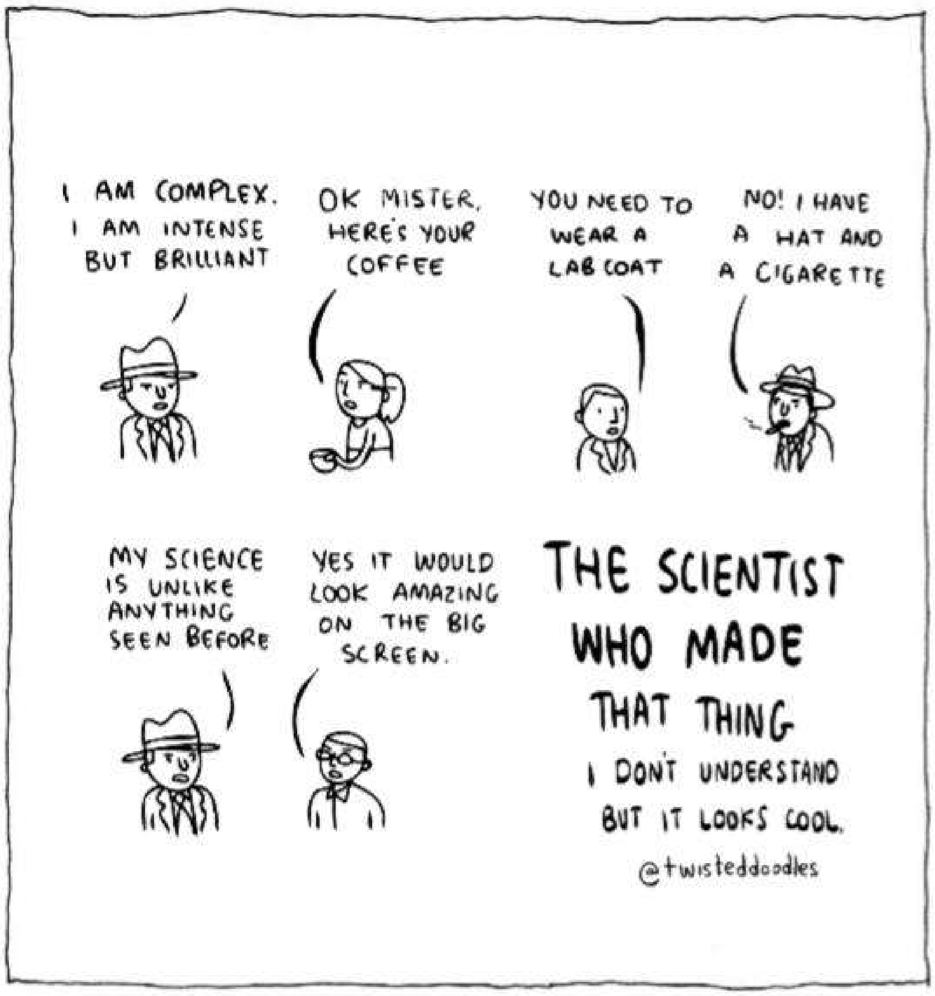
Di Wang, Shuangxia Han and Ming Yang at Jilin University in China surveyed current knowledge about teeth from many animals, including "human teeth, herbivore and carnivore teeth, shark teeth, calcite teeth in sea urchins, magnetite teeth in chitons, and transparent teeth in dragonfish".

For anyone seeking a potentially scary-sounding term to inject into political discourse, the highlight of the paper is the word "polyphyodont". For that limited, political usage, polyphyodont is most potent for its sound rather than its meaning. (Wang, Han and Yang do supply a definition. They explain that many vertebrates, though not most mammals, "are polyphyodont, continuously replacing worn teeth throughout the lifetime".)

Politicians who give a hoot about what science has to offer (in addition to big scary words) might notice the stated purpose of this tooth diversity study. The authors say they hope to "stimulate further efforts in the synthesis of tooth-inspired materials". Their paper includes photos of "A claw-like device inspired by sea urchin teeth". Those photos are reprinted from a paper co-authored in 2016 by Steven Naleway, who five years later was awarded an Ig Nobel peace prize for a rather different research project.

Naleway's Ig Nobel prize-winning work produced knowledge of value to people whose followers are filled with all-purpose anger. Naleway, together with colleagues Ethan Beseris and David Carrier, tested the hypothesis that humans evolved beards to protect against punches to the face.

Twisteddoodles *for New Scientist*


I AM COMPLEX. I AM INTENSE BUT BRILLIANT
OK MISTER, HERE'S YOUR COFFEE
YOU NEED TO WEAR A LAB COAT
NO! I HAVE A HAT AND A CIGARETTE
MY SCIENCE IS UNLIKE ANYTHING SEEN BEFORE
YES IT WOULD LOOK AMAZING ON THE BIG SCREEN.
THE SCIENTIST WHO MADE THAT THING
I DON'T UNDERSTAND BUT IT LOOKS COOL.
@twisteddoodles

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Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Crepitus, for the children

One way to give children a healthy fascination with science is to teach them some technical word that – they can hope – will disgust adults.

"Crepitus" is a fine word to feed to kids for this educational purpose. "Crepitation" is an equally good word that means the same thing: any grinding, scraping, creaking, cracking, clunking, grating, crunching or other sound that comes from a person's body parts.

Crepitus (the ailment, though maybe not its name) is especially on the minds of middle-aged athletes who, alarmed they have noisy knees, seek medical advice. Is knee noise a harbinger of disaster? Will exercise make it worse?

Alexandre Kovats and his colleagues at the University of New South Wales in Australia have news for medical advisers to pass on to clickety-clack-kneed patients. After scouring much of the medical literature about knee crepitus, they quietly sound off in the *Journal of Clinical Exercise Physiology*. "Knee crepitus," they write, "is unlikely to change in individuals with established [knee osteoarthritis] following exercise. Thus, Exercise Physiologists can provide reassurance to people who are concerned about their noisy joints that exercise should not exacerbate symptoms."

Fourfold superpower

Claire Haresnape Tyson adds a seasonal, colourful detection skill to Feedback's growing catalogue of trivial superpowers. She says: "My super power is the ability to find four leaf clovers. I will find them regularly during the spring and summer. I have shared this super power with my husband. Friends regularly lament that they never find one." Claire sent a photo (above) documenting one of her discoveries. ▮

Marc Abrahams

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